Sex- and season-based comparison of lipid and fatty acid profiles of blue crab meat

YUNUS ALPARSLAN – CANSU METIN – TACNUR BAYGAR

Summary
Effects of sex and harvesting season on the lipid and fatty acid profiles of the adult blue crab (*Callinectes sapidus*) muscle from Koycegiz Lagoon (Mugla, Turkey) were investigated using gas chromatography. Lipid contents of female samples were significantly higher ($p < 0.05$) than male samples for all season. The dominant fatty acids were eicosapentaenoic acid (EPA, C20:5 *n*-3), docosahexaenoic acid (DHA, C22:6 *n*-3), oleic acid (C18:0) and palmitic acid (C16:0) for all samples. The *n*-6/*n*-3 ratio was higher in the male crab meat (0.49) than in the female crab meat (0.44) in autumn and winter season, respectively. Sum of *n*-3, *n*-6 fatty acids and polyunsaturated fatty acid (PUFA) level of male crab meat was higher than female blue crabs in all seasons. Sum of monounsaturated fatty acids (MUFA) of all groups was found to be lower than the saturated fatty acids (SFA), which was significantly marked for male individuals during spring and summer season. Similarly, male crabs had high PUFA content in spring and summer while it was low in autumn and winter. Crab meat was found to be an appropriate source of *n*-3 fatty acids. The results of the study demonstrated that fatty acid profiles display significant differences depending on the sex of the crab.

Keywords
Callinectes sapidus, fatty acid profile; eicosapentaenoic acid; docosahexaenoic acid

Blue crab (*Callinectes sapidus*) is an economically important shellfish. It is also popular for recreational fishing. It is abundant in the North American Coast, North-Eastern Mediterranean Sea and surrounding waters. In Turkey, it is caught abundantly in the Mediterranean Sea mostly, almost 95 %, on the coasts [1]. Blue crab consumption is known to provide health benefits due to its content of proteins, vitamins and unsaturated essential fatty acids.

Lipids and their constituent fatty acids are, along with proteins, the major organic constituents of marine organisms [2, 3]. In particular, highly unsaturated fatty acids (HUFA) play an important role in nutrition thanks to their role in critical physiological processes [3]. Crustaceans contain significant quantities of HUFA [2]. The lipid content of marine species may vary depending on endogenous and exogenous effects [4, 5]. SIEIRO et al. [6] reported that there is a heterogeneous lipid distribution throughout the body of marine species, which migth be related to the physiological factors. It was indicated by many authors that factors such as sexual maturation, nutrition availability and water temperature might effect the fatty acid composition and lipid contents of fish species [1, 7, 8]. Similar to studies on fish species, there are numerous studies on fatty acid composition of various body parts of crab species [1, 8–14].

Koycegiz Lagoon is located in the province of Mugla at the southern Aegean coast of Turkey. Along the Aegean coast, it is the most productive fisheries area, which is supported by the system of lake, river and lagoons [15]. The aim of the present study was to investigate the effects of sex and season on the lipid and fatty acids composition of blue crab muscle that were caught in the Koycegiz Lagoon.

MATERIALS AND METHODS

Samples

Blue crabs (*C. sapidus*) were harvested from the Koycegiz Lagoon (Mugla, Turkey; 36°47’41”N, 28°37’18”E) in 2018 and 2019 seasons. Samples

Yunus Alparslan, Cansu Metin, Tacnur Baygar, Department of Seafood Processing Technology, Faculty of Fisheries, Mugla Sitki Kocman University, Sitki Kocman Street, 48000 Mugla, Turkey.

Correspondence author:
Yunus Alparslan, e-mail: yunusalparslan@mu.edu.tr

(20 individuals for each sex and each season) were transferred alive (packaged in a freezing insulated polystyrene box) to the Quality Control Laboratory of Faculty of Fisheries (Mugla Sitki Kocman University, Mugla, Turkey) within 3 h after harvest. The species of the crab, which was harvested on January (for winter season sampling), April (for spring season sampling), July (for summer season sampling) and October (for autumn season sampling), were identified and total weight, the carapace width as well as length were measured. Claw portions and body meat of crabs meat were separated and mixed for the lipid and fatty acid analysis Analysis were performed in duplicate samples of the homogenates.

Fatty acids analysis

Lipid extraction was done according to BLIGH and DYER method [16]. Fatty acid methyl esters (FAME) were prepared by transmethylation using 2 mol·l^{-1} KOH in methanol and *n*-hexane, according to the method described by ICHIHARA et al. [17], with a minor modification. Oil extracted from crab meat (10 mg) was dissolved in 2 ml of *n*-hexane and 4 ml of 2 mol·l^{-1} methanolic KOH was added. The tube was then mixed by vortex for 2 min at room temperature (24 ± 1 °C). The mixture was centrifuged at 900 ×*g* for 10 min and the *n*-hexane layer was taken for analysis by gas chromatography (GC).

FAME were analysed using model 7820 gas chromatograph (Agilent Technologies, Santa Clara, California, USA) equipped with a split/splitless injector and flame ionization detector (FID). An HP-88 capillary column (60 m × 0.25 mm × 0.25 μm, Agilent Technologies) was used. The injection was conducted in a splitless mode for 1 min at 250 °C. Hydrogen was used as the carrier gas with a flow rate of 20 ml·min^{-1}. The oven temperature was programmed at an initial 75 °C for 5 min, increased to 120 °C at a rate of 15 °C·min^{-1} and maintained for 1 min, ramped to 175 °C at 5 °C·min^{-1} and held for 5 min, finally increased to 220 °C for 5 min. The flow rate of hydrogen was 40 ml·min^{-1} and of air was 400 ml·min^{-1}. [18].

Identification of fatty acids was carried out by comparing the relative retention time of sample FAME peak with those obtained for standards (37 compounds FAME mix, 10 mg·ml^{-1} in CH_2Cl_2, Supelco, Bellefonte, Pennsylvania, USA and Ampule FAME mix C4–C24, Agilent Technologies). Results for each fatty acid were expressed as FID response area relative percentages of the total fatty acids determined [18].

Statistical analysis

Data were presented as mean values ± standard deviations and a probability value of $p < 0.05$ was considered significant. Statistical analysis of data was carried out with SPSS statistics 22 software program (IBM, Armonk, New York, USA). The differences were calculated both using one-way analysis of variance (ANOVA) and using the Duncan's multiple range test (at a 5% confidence level) to evaluate the effect of gender and season on the lipid and fatty acid composition.

RESULTS AND DISCUSSION

The average width and length of carapace were 6.5 ± 0.78 cm and 16.0 ± 2.14 cm for female blue crab, and 6.1 ± 0.80 cm and 14.5 ± 1.80 cm for male blue crab, respectively. The average weights of female and male blue crab were 210.68 ± 62.42 g and 208.02 ± 73.74 g, respectively. ATAR and SECER [19] reported that the carapace width of the 1 027 crabs that were harvested from Beymelek Lagoon lake, Antalya ranged from 5.1 cm to 18.1 cm and the weight ranged from 8.92 g to 448 g. The average width and length of blue crabs in the study of ATAR and SECER [19] were found similar with our study.

Data on lipid composition of the male and female blue crabs meat are presented in Tab. 1. The results reveal that the lipid composition was significantly different between female and male blue crab meat in winter. It was reported that, for blue crabs, the total lipid contents were significantly related to gender [20]. In this study, the content of total lipids was higher in the female crab meat

Tab. 1. Lipid contents of blue crab meat.

	Lipid content [g·kg^{-1}]			
	Autumn	Winter	Spring	Summer
Female	9 ± 1^{bA}	13 ± 2^{aA}	9 ± 1^{bA}	9 ± 1^{bA}
Male	8 ± 0^{bA}	12 ± 2^{aA}	8 ± 1^{bA}	8 ± 0^{bA}

In each row, different lower-case superscript letters denote significant differences among seasonally and in each column with upper-case superscript letters denote significant differences among genders ($p < 0.05$).

than the male crab meat throughout the season. Moreover, for both male and female crabs the lipid content was found higher in winter ($p < 0.05$). Luvizotto-Santos et al. [21] found higher lipid content in winter than in summer in several tissues (gills, muscle, and hepatopancreas) of estuarine crab (*Chasmagnathus granulate*) and pointed to a metabolic strategy used by crustaceans to store high energy compounds that will be useful during winter adversities. Similarly, García-Soto et al. [22] determined the lipid content of crustacean (*Munida* spp.) higher in winter (0.9 %) than in summer (0.7 %). Also, Latyshev et al. [11] indicated that such differences in the lipid content of muscles might be due to the different inhabiting conditions or moulting stages of crabs. In our study, the lipid content of blue crabs was higher in winter than in summer, which was similar with the results of García-Soto et al. [22].

As a feature of decapods, a low lipid content of crabs was reported as $< 20\,g{\cdot}kg^{-1}$ in several studies including Kuley et al. [9] and Ayas [23]. Ayas [23] indicated similar levels of lipid content for swimming crab (*Portunus segnis*) and blue crab (*C. sapidus*). The author also reported that higher lipid contents were determined in spring and winter while lower lipid contents were calculated in summer and autumn for both sexes and muscle types. Similar fat composition results of adult female crab species were reported as 12.0 $g{\cdot}kg^{-1}$ fat for swimming crab (*Portunus trituberculatus*) [24] and 10.8 $g{\cdot}kg^{-1}$ fat for blue swim crab (*Portunus pelagicus*) [25]. Kucukgulmez et al. [26] reported the fat content of blue crab claw meat and breast meat as 4.4 $g{\cdot}kg^{-1}$. The fat content in meats of *Callinectes pallidus* and *Cardisoma armatum* were found to be 2.09 $mg{\cdot}kg^{-1}$ and 1.65 $mg{\cdot}kg^{-1}$, respectively [27]. It was indicated that there were seasonal fluctuations in fat content of brown meat of *Cancer pagurus* from the Scottish coast, whose fat content was lower in crabs caught during spring than in crabs caught during summer [28]. Lipid content of seafood is possibly affected by environment, season, gender, sexual changes in connection with spawning and period of carapace change [13, 29]. The lipid content of crabs in the study of He et al. [24] and Kücükgülmez et al. [26] were similar with our study, but Elegbede and Fashina-Bombata [27] reported values lower than found in our study.

Data on fatty acids composition, contents of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), *n*-3, *n*-6 and the *n*-6/*n*-3 ratio of male and female blue crabs meat are presented in Tab. 2. Significant differences were observed among the type of some fatty acids depending on the sex and seasons ($p < 0.05$). In all seasons, PUFA were the main group of fatty acids in muscle, which was followed by SFA and MUFA. The major fatty acids detected in both male and female blue crabs were C16:0 (palmitic), C18:0 (stearic), C18:1*n*-9 (oleic), C20:5*n*-3 (EPA) and C22:6*n*-3 (DHA). Blue crab female meat was found to contain significantly higher proportions of C14:0, C20:0, C18:1*n*-9, C20:1*n*-9, C22:1*n*-9, C18:2*n*-6 and C20:3*n*-6, together with lower proportions of C16:0, C18:0, C20:4*n*-6, C20:5*n*-3, C22:4*n*-3, C22:5*n*-3 and C22:6*n*-3 than in male meat ($p < 0.05$). Cherif et al. [10] reported the main fatty acids of the claw meat of green crab as palmitic acid (C16:0), stearic acid (C18:0) and oleic acid (C18:1) in the claw meat. Naczk et al. [30] reported the main saturated fatty acids of green crab (*Carcinus maenas*) meat as palmitic (C16:0) and stearic (C18:0) acids, while oleic acid (C18:1) was the dominant monounsaturated fatty. In the same report, the levels of SFA, MUFA and PUFA were reported as 18.1–20.7 %, 24.2–25.7 % and 47.1–50.5 %, respectively. Wu et al. [25] reported the SFA, MUFA and PUFA values in blue swimmer crab (*Portunus pelagicus*) as 25.4–36.3 %, 23.4–32.4 % and 19.1–42.1 %, respectively. Our determined values on SFA and MUFA were similar but on PUFA were higher than those determined for blue swimmer crab in a study of Wu et al. [25].

Depending on the season, the sum of SFA levels were found to be 28.1 %, 25.0 %, 26.3 % and 29.2 % for male blue crab, and 29.0 %, 26.9 %, 26.2 % and 30.2 % for female crab in autumn, winter, spring, and summer, respectively. Palmitic acid (14.0–16.2 %) was the major SFA in all crab meats. The highest C17:0 and SFA levels for both female and male blue crabs were obtained in summer. Bayrakli [31] found the highest SFA (35.8 ± 0.8 %) in March for warty crab (*Eriphia verrucosa*) from the Southern Coast of Black Sea, Turkey. The highest SFA in March for warty crab was higher than SFA for blue crab in our study. Sum of SFA were found to be the minor group of fatty acids of male and female blue crabs in all the seasons. SFA of male and female blue swimmer crabs were reported as C14:0 (0.6 % and 1.0 %), C16:0 (13.1 % and 13.0 %) and C18:0 (9.1 % and 9.9 %), respectively [25]. Similarly, Ayas and Ozogul [13] also reported the fatty acids of male and female *C. sapidus* as C14:0 (0.7 % and 0.8 %), C16:0 (13.6 % and 14.2 %), C18:0 (6.4 % and 6.9 %), C20:0 (0.7 % and 0.8 %) and C22:0 (0.0 % and 0.0 %), respectively. C14:0, C16:0 and C18:0

Tab. 2. Fatty acid composition of female and male blue crab meat.

Fatty acids [%]	Autumn		Winter		Spring		Summer	
	F	M	F	M	F	M	F	M
C12:0	0.3 ± 0.2^{a}	0.1 ± 0.2^{b}	0.2 ± 0.1^{a}	0.2 ± 0.1^{a}	0.0 ± 0.1^{b}	0.2 ± 0.3^{a}	0.1 ± 0.2^{a}	0.0 ± 0.1^{a}
C14:0	1.1 ± 0.1^{a}	0.8 ± 0.1^{b}	1.7 ± 0.6^{a}	1.1 ± 0.9^{b}	0.9 ± 0.1^{a}	1.1 ± 0.8^{a}	0.8 ± 0.2^{a}	0.7 ± 0.1^{a}
C15:0	0.5 ± 0.1^{a}	0.3 ± 0.3^{a}	0.8 ± 0.4^{a}	0.4 ± 0.0^{b}	0.5 ± 0.0^{a}	0.4 ± 0.0^{a}	0.8 ± 0.0^{a}	0.7 ± 0.2^{a}
C16:0	16.2 ± 1.4^{a}	14.8 ± 1.1^{b}	15.0 ± 2.1^{a}	15.0 ± 2.1^{a}	15.3 ± 0.6^{a}	14.4 ± 0.4^{a}	16.1 ± 1.1^{a}	14.0 ± 0.6^{b}
C17:0	1.5 ± 0.1^{a}	1.8 ± 0.2^{a}	1.7 ± 0.5^{a}	1.2 ± 0.2^{b}	1.4 ± 0.2^{a}	1.3 ± 0.2^{a}	1.9 ± 0.2^{b}	2.6 ± 0.4^{a}
C18:0	8.7 ± 0.7^{a}	9.4 ± 0.7^{b}	6.5 ± 0.1^{a}	6.5 ± 0.3^{a}	7.4 ± 1.2^{b}	8.5 ± 1.1^{a}	9.3 ± 1.2^{b}	10.6 ± 0.4^{a}
C24:0	0.5 ± 0.5^{a}	0.6 ± 0.5^{a}	0.8 ± 0.1^{a}	0.3 ± 0.3^{b}	0.3 ± 0.3^{a}	0.2 ± 0.2^{a}	1.0 ± 0.2^{a}	0.3 ± 0.6^{b}
SFA	29.0 ± 0.6^{a}	28.1 ± 1.3^{a}	26.9 ± 1.8^{a}	25.0 ± 2.7^{b}	26.2 ± 1.4^{a}	26.3 ± 1.8^{a}	30.2 ± 0.4^{a}	29.2 ± 1.3^{a}
C16:1	4.3 ± 1.0^{c}	3.4 ± 0.5^{b}	6.2 ± 0.2^{a}	4.9 ± 1.4^{a}	5.0 ± 1.0^{bc}	3.0 ± 0.5^{c}	5.5 ± 1.8^{b}	3.6 ± 0.6^{b}
C17:1	0.7 ± 0.1^{c}	0.7 ± 0.3^{c}	1.0 ± 1.0^{a}	1.0 ± 0.3^{b}	1.0 ± 0.2^{a}	0.9 ± 0.2^{b}	1.2 ± 0.1^{b}	1.5 ± 0.7^{a}
C18:1 *n*-9t	0.7 ± 0.3^{a}	0.6 ± 0.1^{a}	0.4 ± 0.0^{b}	0.4 ± 0.2^{b}	0.2 ± 0.2^{c}	0.3 ± 0.0^{c}	0.4 ± 0.0^{b}	0.4 ± 0.3^{bc}
C18:1 *n*-9c	14.3 ± 0.7^{a}	15.3 ± 1.9^{a}	13.6 ± 1.3^{c}	15.5 ± 3.2^{a}	14.0 ± 0.8^{ab}	13.5 ± 0.2^{b}	13.7 ± 0.6^{bc}	12.6 ± 1.8^{c}
C20:1 *n*-9	1.6 ± 1.0^{a}	1.3 ± 0.6^{a}	0.9 ± 0.3^{b}	0.7 ± 0.2^{b}	0.8 ± 0.3^{b}	0.7 ± 0.1^{b}	0.7 ± 0.1^{b}	0.6 ± 0.1^{b}
MUFA	21.7 ± 2.0^{a}	21.4 ± 0.8^{a}	22.6 ± 2.7^{a}	22.6 ± 1.8^{a}	21.2 ± 2.5^{a}	18.5 ± 0.7^{b}	21.7 ± 1.1^{a}	18.9 ± 2.3^{b}
C18:2 *n*-6c	4.5 ± 0.4^{a}	5.1 ± 1.8^{a}	3.0 ± 0.7^{b}	4.1 ± 0.1^{b}	4.1 ± 0.7^{a}	4.6 ± 0.7^{b}	3.1 ± 1.4^{b}	4.4 ± 1.2^{b}
C18:3 *n*-6	0.1 ± 0.3^{b}	0.1 ± 0.2^{b}	0.3 ± 0.3^{a}	0.1 ± 0.3^{a}	0.1 ± 0.1^{b}	0.1 ± 0.1^{a}	0.4 ± 0.5^{a}	0.0 ± 0.0^{c}
C18:3 *n*-3	0.0 ± 0.0^{c}	0.0 ± 0.0^{b}	0.7 ± 0.7^{a}	0.0 ± 0.0^{b}	0.3 ± 0.3^{b}	0.2 ± 0.2^{a}	0.6 ± 0.6^{a}	0.2 ± 0.3^{a}
C20:2	0.7 ± 0.6^{a}	0.7 ± 0.3^{b}	0.5 ± 0.1^{b}	0.6 ± 0.1^{c}	0.7 ± 0.0^{a}	0.8 ± 0.0^{ab}	0.7 ± 0.2^{a}	0.9 ± 0.3^{a}
C20:3 *n*-6	0.0 ± 0.0^{b}	0.0 ± 0.0^{b}	0.18 ± 0.3^{a}	0.0 ± 0.0^{b}	0.1 ± 0.1^{a}	0.1 ± 0.1^{a}	0.0 ± 0.0^{b}	0.0 ± 0.0^{b}
C20:4 *n*-6	6.8 ± 1.9^{c}	8.0 ± 0.3^{b}	8.1 ± 1.1^{a}	7.7 ± 1.4^{b}	6.7 ± 2.0^{c}	7.4 ± 0.8^{c}	7.9 ± 2.2^{b}	8.5 ± 0.1^{a}
C20:5 *n*-3	15.0 ± 1.1^{b}	14.5 ± 1.6^{c}	14.1 ± 1.8^{c}	14.0 ± 1.3^{c}	15.0 ± 2.8^{b}	16.9 ± 1.0^{a}	16.3 ± 0.6^{a}	16.0 ± 1.4^{b}
C22:6 *n*-3	12.2 ± 1.9^{b}	13.0 ± 0.8^{c}	12.3 ± 3.4^{b}	14.9 ± 2.3^{b}	13.8 ± 1.3^{a}	15.9 ± 0.7^{a}	11.1 ± 1.0^{c}	13.0 ± 0.8^{c}
PUFA	39.5 ± 1.6^{b}	41.7 ± 1.5^{a}	39.5 ± 1.3^{b}	41.6 ± 0.7^{a}	41.1 ± 1.3^{b}	46.5 ± 0.9^{a}	40.4 ± 1.8^{b}	43.1 ± 2.9^{a}
n-3	27.3 ± 2.0^{a}	27.6 ± 2.2^{a}	27.1 ± 2.3^{b}	28.9 ± 1.3^{a}	29.2 ± 1.9^{b}	34.1 ± 0.7^{a}	28.2 ± 1.0^{a}	29.2 ± 1.6^{a}
n-6	11.5 ± 2.6^{b}	13.4 ± 1.4^{a}	11.8 ± 0.8^{a}	12.0 ± 1.2^{a}	11.1 ± 1.9^{a}	11.5 ± 0.1^{a}	11.4 ± 3.0^{b}	12.9 ± 1.1^{a}
n-6/*n*-3	0.4 ± 0.0^{a}	0.4 ± 0.0^{a}	0.4 ± 0.0^{a}	0.4 ± 0.0^{a}	0.3 ± 0.1^{a}	0.3 ± 0.0^{a}	0.4 ± 0.1^{a}	0.4 ± 0.0^{a}
PUFA/SFA	1.3 ± 0.1^{a}	1.4 ± 0.4^{a}	1.4 ± 0.0^{b}	1.6 ± 0.2^{a}	1.5 ± 0.0^{b}	1.7 ± 0.1^{a}	1.3 ± 0.3^{a}	1.4 ± 0.0^{a}
EPA/DHA	1.2 ± 0.2^{a}	1.1 ± 0.0^{a}	1.1 ± 0.4^{a}	0.9 ± 0.2^{b}	1.0 ± 0.1^{a}	1.0 ± 0.1^{a}	1.4 ± 0.2^{a}	1.2 ± 0.1^{b}
Undefined	9.6 ± 1.0^{a}	8.6 ± 1.1^{b}	10.8 ± 0.1^{a}	10.5 ± 2.4^{a}	11.3 ± 2.2^{a}	8.4 ± 2.1^{b}	7.6 ± 0.2^{b}	8.6 ± 1.8^{a}

In each row, different lower-case superscript letters denote significant differences among season samples ($p < 0.05$).
F – female, M – male, SFA – saturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids, EPA – eicosapentaenoic acid, DHA – docosahexaenoic acid.

in the study of Ayas and Ozogul [13] and Wu et al. [25] were similar with these SFA in our study.

The sum of MUFA levels were found to be 21.4 %, 22.6 %, 18.5 % and 18.9 % for male blue crab; 21.7 %, 22.6 %, 21.2 % and 21.7 % for female crab in autumn, winter, spring, and summer, respectively. In spring and summer, the sum of MUFA levels of female blue crab were higher than of male blue crabs. Javaheri Baboli et al. [14] reported that C18:1*n*-9 and C16:1*n*-7 were the major fatty acids of male and female blue swimmer crab (*P. pelagicus*) among MUFA. In the same study, oleic acid (13.6–21.0%) was found to be the major MUFA in blue swimmer crab meat, which was followed by palmitoleic acid (6.5–12.0 %) and octadecenoic acid (1.8–2.4 %). For the same species (*P. pelagicus*), which was harvested from Beibu Gulf, Wu et al. [25] reported oleic acid (C18:1) and palmitoleic acid (C16:1) values as 13.2–13.8 % and 4.8–7.8 %, respectively. Kuley et al. [9] determined that oleic acid (18:1), palmitoleic acid (16:1) and heptadecanoic acid (17:1) were the major MUFAs in *C. sapidus*. Similarly, oleic acid and palmitoleic acid were the major MUFA in our study.

The total PUFA value was highest (46.5 %) in meat of male crabs while the lowest amounts (39.5 %) were recorded in meat of female blue crabs. The sum of PUFA levels were found to be 39.5 %, 39.5 %, 41.1 % and 40.4 % for female blue crab; 41.7 %, 41.6 %, 46.5 % and 43.1 % for male crab in autumn, winter, spring, and summer, respectively. As marine lipids are reported to be a great deal of attention due to their high content of *n*-3 PUFA [22], *n*-3 PUFA values of the blue crab meat were found to be significantly high for all seasons. [22]. Bayrakli [31] determined the highest PUFA in August and October (50.7 ± 0.1 % and 50.8 ± 1.3 %, respectively) and the lowest in May (34.6 ± 2.7 %). Sum of *n*-3, *n*-6 and PUFA levels of male crab meat were found to be higher than female blue crabs in all seasons. In this study, among these, sum of PUFA contents of male crabs were recorded as high in spring-summer periods similarly with the study of Bayrakli [31] while they were low in autumn-winter periods.

EPA contents in meat of female blue crabs were higher than those of the males (except from spring season). For the male crab meat, arachidonic acid (C20:4*n*-6) content reached the highest value in summer. The male crab meat had significantly higher total *n*-3 fatty acid content in spring when compared to the female crab meat ($p < 0.05$). Total EPA (C20:5*n*-3) and DHA (C22:6*n*-3) contents were 14.5–13.0 % and 5.0–12.2 % (in autumn), 14.0–14.9 % and 14.1–12.3 % (in winter), 16.9–15.9 % and 15.0–13.8 % (in spring) and 16.0–13.0 % and 16.3–11.1 % (in summer) for male and female crab meat, respectively.

DHA was reported to contribute to the development of certain physiological functions related to the nervous system and visual functions in human beings, while EPA has been reported to be beneficial for human health as it reduces the risk of cardiovascular diseases [22]. The results of the analysis of fatty acid composition indicated that crabs were very rich in *n*-3 fatty acids, in particular EPA and DHA. According to Kuley et al. [9], PUFA were the dominant fatty acids of blue crab (*C. sapidus*). Celik et al. [8] indicated that the total EPA and DHA contents of claw meat, breast meat and hepatopancreas of the crab were, on average, 106 g·kg^{-1} and 84 g·kg^{-1}, 77 g·kg^{-1} and 59 g·kg^{-1}, 67 g·kg^{-1} and 53 g·kg^{-1}, respectively. The fatty acid profile of lipids was dominated by PUFA (36.1–37.3 %) and total *n*-6 (13.9–15.0 %) in the claw meat of green crab [10]. In another study, male crabs (*P. pelagicus*) had higher C22:6*n*-3 fatty acid content than the females [25]. García-Soto et al. [22] found lower PUFA, DHA, EPA and *n*-3 in winter compared with summer for a crustacean (*Munida* spp.). Similarly, in the present study, sum of PUFA, EPA and *n*-3 were higher in spring and summer, especially for male crab. Male crab meat (34.1 %) and female crab meat (29.2 %) had higher amounts of total *n*-3 fatty acids in spring than in other seasons. Total *n*-6 fatty acids of the male crab meat had lower value than the female crab meat. Nutritionists suggested that the ratio of *n*-6/*n*-3 should be 0.1–0.2 while the higher ratios (> 0.2) are more functional for human health [14]. The UK Committee on Medical Aspects of Food Policy recommends a maximum *n*-6/*n*-3 ratio of 4.0 [32]. It is indicated that higher values might be harmful for human health which may promote the cardiovascular diseases [33]. In the present study, the *n*-6/*n*-3 ratio was found to range from 0.38 to 0.44 for female and 0.34 to 0.49 for male. Our results were in accordance with Javaheri Baboli et al. [14] who suggested that the ratio of *n*-6/*n*-3 fatty acids should be 0.1–0.2 while higher ratios (> 0.2) are better for human health. However, *n*-6/*n*-3 values below the maximum ratio of 4.0 were recommended by UK Committee on Medical Aspects of Food Policy [32] emphasizing that higher values might be harmful to human health regarding promotion of cardiovascular diseases [33]. The PUFA/SFA ratio was calculated to range from 1.34 to 1.57 for female crabs and 1.48 to 1.76 for male crabs which was higher than the recommended value of 0.45 [9, 32]. Throughout the four

seasons, DHA and PUFA contents of male crabs were found to be higher than those of the female crabs, while EPA content was significantly higher than that for both genders.

CONCLUSIONS

The results obtained in this study showed that male and female crab meat is an important fatty acid source especially for *n*-3 fatty acids, EPA and DHA. Fatty acid composition analysis that was performed in all seasons displayed that male crab meat had higher contents of summed *n*-3 fatty acids (especially DHA), *n*-6 fatty acids and PUFA than the female meat. Generally, this study recommends that blue crab meat is an important source of valuable fatty acids. For containing high amounts of essential fatty acid, male blue crab consumption might be strongly advised to meet the nutritional requirements of *n*-3 fatty acids (DHA and EPA) to promote human health.

Acknowledgements

The authors wish to thank to DALKO (Dalyan Fisheries Cooperative, Mugla, Turkey) for providing the samples and to Ismail Reis for biometric measurements of blue crabs.

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Received 15 June 2021; 1st revised 19 November 2021; accepted 8 December 2021; published online 18 January 2022.