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Seasonal Variations in Proximate and Fatty Acid Composition of Muscle of Tunisian Grass Goby Zosterisessor Ophiocephalus

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ABSTRACT

The present study focuses on the seasonal variation of the global chemical composition of Gradd goby, *Zosterisessor ophiocephalus*, of the coastal catch from the Gabes Gulf (Tunisia). The variations of moisture, protein fat and ash contents of the fresh muscle fish were examined as a function of sex. These variations are low for moisture and fat and medium for protein and ash. The highest moisture content was reached during July for males (82.25 ± 0.70 g/ 100 g of fresh muscle) and during November for females (73.68 ± 0.65 g/ 100 g of fresh muscle). Over the year, this fish present lower fat content. However, higher protein values were observed over the year (15.27-21.33 g/ 100g of fresh muscle). Interestingly, muscle of *Zosterisessor ophiocephalus* may constitute a source of protein with lower fat content suggesting the use of this fish as a flower of healthy diet for humans. Significant differences were also observed for fatty acids. Palmitic acid was the most abundant fatty acid ranging from 20.57 % to 34.90 %. Oleic acid was the main unsaturated fatty acid ranging from 24.12 % to 43.47 %. The muscle contained high rate of ω-3 polyunsaturated fatty acids (PUFA), ranging from 7.58 to 20.07 %.

Keywords

Zosterisessor ophiocephalus, coastal catch, chemical composition, fatty acid, fish muscle

Introduction

The nutritional importance of fish consumption is in great extent associated with its beneficial biochemical composition specifically fatty acids [1]. Annually, more than 100 million tons of fish and shellfish are caught [2]. Variations in global chemical composition (moisture, protein, ash, fat and fatty acid) between and within fish species depend on various factors, such as food availability, the season, location, sex, body size, stage of sexual maturity, diet and age [3,4,5]. For example, large variation of fat and fatty acid composition was observed between fish-tissues. It was reported that liver is an important organ in terms of fat metabolism and the main part of fish used for human nutrition is generally muscle. Interestingly, cod liver oil has been a commercial health care product in Northern Europe for centuries [6]. In this perspective, many studies were conducted on the beneficial health properties of polyunsaturated fatty acids (PUFAs). Specifically, ω-3 fatty acids are known to exert therapeutic attributes on human cardiovascular diseases, hypertension autoimmune disorders and proper neural development [7]. Particularly, eicosapentaenoic acid (C20:5; EPA) and docosahexaenoic acid (C22:6; DHA) [8], derived from phytoplankton and seaweed in the food chain [9], showed to have beneficial effects on bone formation and metabolism, and in the prevention of cardiovascular disease [10,11,12]. Moreover, ω-3 PUFAs can not be synthesized effectively by humans [13] and must be obtained by diet [14]. Like other vertebrates, fish also require EPA, DHA and arachidonic acid (C20:4 ω6; ARA) for normal growth, development and reproduction [15,16]. Moreover, it was reported that these PUFAs are necessary to maintain membrane structure integrity and are precursors of eicosanoids [16].

In Tunisia, the fishing sector occupies a very important place in the socioeconomic development and has been recognized as a powerful income and employment generator. Therefore, in order to use fish sources as good as possible, is very important to elucidate many factors regarding the fishing sector including the amount of fish, the available species and the biochemical composition variation over the year. For example, is very interesting to give clear view on the Tunisian goby species. Interestingly, some of the gobies are resource for the can food industry for many Black Sea countries. Grass goby, *Zosterisessor ophiocephalus* (Gobiidae) is an abundant specie in Tunisia and seems to have an economic importance for the local communities. Generally, this specie lives in the inshore and brackish water of estuaries and lagoons of the Mediterranean, Black Sea, Adriatic Sea and Sea of Azov [17]. In the Adriatic, especially on the Eastern coast, it has some local economical importance, mostly living and reproducing in coastal waters and estuaries during its whole life cycle (sexually mature at two or three years; lifespan is five years) [17].

In Tunisia, goby species are not until now well utilized. In order to explore this fish, knowledge about the biochemical composition is needed. Hence, the purpose of this study was to examine the seasonal changes over the year in moisture, protein, ash, fat and mineral contents in the muscle of *Zosterisessor ophiocephalus* caught in the Gulf of Gabes area.

MATERIALS AND METHODS

Raw material preparation and analyses

Fish samples were obtained monthly over the year. *Zosterisessor ophiocephalus* specie was caught from Gabes gulf area (Tunisia). Fishes were rapidly transported on ice to the laboratory for preparation to chemical analyses. The length (14-17 cm) and weight (30- 60 g) of the whole fish were measured in order to select homogenous samples (superior to sexual maturity size). Weight of samples was determined by using a precision scale 10^{-4} g (Sauter). Several organs (liver, head, gonads and viscera) and muscles were dissected. Only muscle of this fish was chosen for the present work. Further, females and males were analyzed separately because the species shows sexual dimorphism.

Moisture content was measured for every ten samples (both males and females) after dehydration in an oven at 105°C to a constant weight (for 48 h). Then, dry samples were homogenized by a meat grinder. The moisture analysis was repeated 10 times. The fish dry powder of fish muscle was divided in 3 parts and used to determine the protein, fat and ash contents. Fat content was quantified by Soxhlet extraction, proteins by Kjeldahl procedure, and ash by incineration in a muffle furnace at 550°C [18]. Analyses were repeated three times and performed over the year.

In order to determine fatty acid composition, the method of Bligh and Dyer [19] was used. A homogenized fresh sample (25 g) was extracted using chloroform/methanol/water mixture (5V/10V/5V). Fats extracts were converted into fatty acid methyl esters (FAME) by using acetylchloride and were then analyzed by gas-liquid chromatography (Perkin-Elmer 8700 chromatograph, Madrid, Spain) [20]. A fused silica capillary column SP-2330 (0.25 mm × 50 m, Supelco, Inc., Bellefonte, PA, USA) was employed and the temperature program was as follows: increased from 145 to 190 °C at 1.0 °C/min and from 190 °C to 210 °C at 5.0 °C/min; held for 13.5 min at 210 °C. The carrier gas was nitrogen at 10 psig and detection was performed with a flame ionization detector at 250 °C. A programmed temperature vaporizer injector was employed in the split mode (150:1) and was heated from 45 to 275 °C at 15 °C/min. Peaks corresponding to FAME were identified by comparing their retention times with those of standard mixtures (Qualmix Fish, Larodan, Malmo, Sweden; FAME Mix, Supelco, Inc.). Peak areas were automatically integrated; 19:0 fatty acid was used as internal standard for quantitative purposes. Content of each fatty acid was expressed as mg kg^{-1} muscle.

The mineral element contents (Ca, Na, Mg, Fe, Zn and K) were determined by an inductively coupled plasma optical emission spectrophotometer (ICP-OES) (Perkin–Elmer, Model 4300 DV, Norwalk, CT) [18].

Estimation of the energetic value of fish muscle

The energetic value (calorific value) of each sample was determined by multiplying the percentages of protein (PC) and fat (FC) contents with their respective standard factors of 4 and 9 kcal/100 g of fish sample [21] and using the following equation:

Caloric value = (4PC + 9FC) kcal/100 g weight.

Statistical analysis

Statistical analysis were performed by using SPSS software® version 11.0 (Statistical Package for Social Sciences). Values are expressed as mean ± error deviation. Variance analysis was performed for moisture, protein, fat and ash contents measured in the muscle according to the factors sex, size of the fish specie to determine the pertinent factors affecting the chemical contents ($p < 0.05$). Correlation matrixes were established between the measured variables (moisture, protein, fat and ash). Honestly significant difference (HSD) with ANOVA one factor was performed for establishing the index of significance for histograms plate. Every factor presenting a p-value (p) inferior to 0.05 was considered significant.

RESULTS

The variations of the chemical composition of *Zosterisessor ophiocephalus* for both fish sexes are presented in Figure 1.

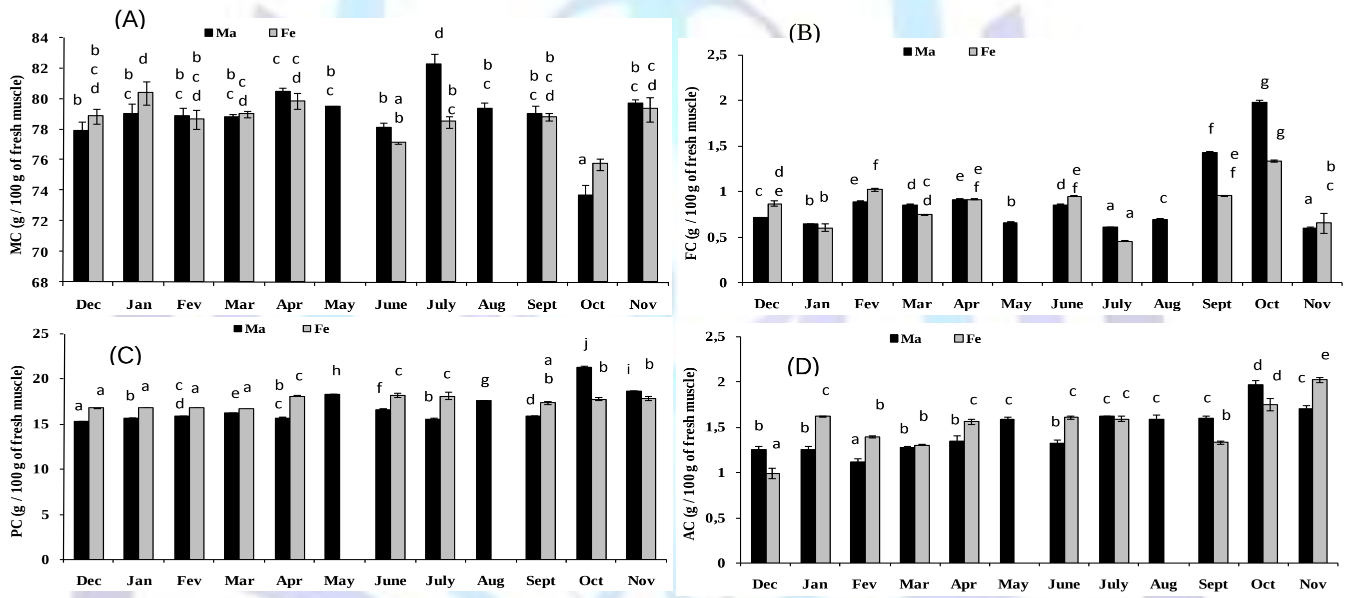

Fig 1: Seasonal variations of Moisture content MC (A), fat content FC (B) protein content PC (C), and ash content AC (D) of Grass goby (*Zosterisessor ophiocephalus*). Values correspond to means of three replicate ± standard deviations of the mean Values followed by the same small letters (a, b, c, d, e, f and g) do not share significant differences at p < 0.05.

Moisture content ranged from 73.68 (in October) to 82.25 % (in July) for males and from 75.74 (in October) to 80.38 % (in January) for females (Figure 1A). Moisture contents are higher over the year (> 73 %). In addition, the fat contents are very low in the same period. Fat content varied from 0.60 (in November) to 1.98 % (in October) for males and from 0.45 (in July) to 1.33% (in October) for females. The average annual fat content of *Zosterisessor ophiocephalus* muscle is about 0.90 % and 0.85 % for males and females, respectively (Figure 1B). The protein contents were high for the fish muscle over the year (> 15 %) with fluctuation in October for males. It varies from 15.27 (in December) to 21.33 % (in October) for males and from 16.70 (in March) to 18.20 % (in June) for females (Figure 1C). For ash contents, the values varied from 1.12 (in February) to 1.97 % (in October) for males and from 0.98 (in December) to 2.02 % (in November) for females (Figure 1D).

The variance analysis of moisture, protein, fat and ash contents according to fish sex, season factors, and the interaction by fish sex and season is presented in Table 1. Only the factor season had a significant effect on ash content ($F= 24.77$; $p = 0.01$). Moreover protein content varied significantly as a function of fish sex season interaction ($p = 0.05$).

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Table 1. Variance analysis of moisture, protein, fat and ash contents of Grass goby (*Zosterisessor ophiocephalus*) according to sexes and season.

Source of variation	Content	F (Fisher number)	p (p-value)
Sex	Moisture	1.53	0.36
	Protein	2.18	0.27
	Fat	3.88	0.15
	Ash	24.77	0.01
Season	Moisture	0.15	0.72
	Protein	1.11	0.37
	Fat	0.44	0.55
	Ash	1.29	0.33
Sex × Season	Moisture	2.45	0.07
	Protein	4.71	0.005
	Fat	2.16	0.10
	Ash	0.75	0.52

Fatty acids composition

The fatty acid profile (Table 2) of muscle of *Zosterisessor ophiocephalus* (for males and females) exhibited a dominance of the saturated fatty acids (SFAs). It varied between 42.35 % (in autumn) and 50.72 % (in winter) and between 34.30% (in summer) and 50.50 % (in spring) for males and females, respectively. For the total monounsaturated fatty acids (MUFAs), values ranged between 27.94% (in winter) and 34.27 % (in spring) and between 29.90 % (in winter) and 44.60% (in summer) for males and females, respectively. However, the total polyunsaturated fatty acids (PUFAs) varied between 16.09 % (in spring) and 26.92 % (in autumn) and between 18.35 % (in spring) and 25.39% (in winter) for males and females, respectively.

Table 2. Seasonal variation of fatty acid in muscle of *Zosterisessor ophiocephalus* (% of total fatty acids); Mean values ± SE.

	Fatty acids	Winter		Spring		Summer		Autumn	
		Male	Female	Male	Female	Male	Female	Male	Female
SFA	C12:0	0.24 ± 0.02	0.24± 0.03	0.23± 0.03	0.23± 0.04	0.20± 0.01	0.26± 0.02	0.26± 0.03	0.23± 0.02
	C14:0	3.41± 0.06	3.14± 0.04	1.50± 0.01	3.16± 0.02	3.32± 0.04	2.91± 0.01	2.74± 0.01	2.23± 0.05
	C15:0	0.95± 0.01	1.10± 0.03	0.64± 0.01	1.20± 0.1	0.58± 0.02	0.78± 0.03	0.54± 0.02	0.61± 0.01
	C16:0	33.16± 0.22	31.18± 0.29	34.90± 0.31	34.61± 0.21	32.17± 0.32	22.36± 0.43	20.57± 0.26	28.66± 0.56
	C17:0	1.50± 0.02	0.96± 0.01	0.66± 0.03	0.55± 0.01	0.40± 0.02	0.93± 0.09	0.85± 0.11	0.76± 0.07
	C18:0	10.09± 0.05	7.70± 0.21	11.15± 0.09	10.18± 0.23	9.30± 0.08	6.40± 0.06	16.37± 0.65	11.43± 0.45
	C20:0	1.35± 0.1	0.36± 0.01	0.53± 0.08	0.55± 0.09	0.63± 0.06	0.64± 0.09	1.01± 0.1	0.60± 0.01
MUFA	C15:1	0.36± 0.01	0.27± 0.02	0.30± 0.01	0.22± 0.03	0.21± 0.02	0.33± 0.01	0.22± 0.03	0.24± 0.02
	C16:1	3.46± 0.01	4.53± 0.01	2.37± 0.01	3.29± 0.01	2.14± 0.01	0.79± 0.01	0.57± 0.01	0.89± 0.01
	C18:1	24.12± 0.1	25.09± 0.11	31.59± 0.21	27.63± 0.17	27.88± 0.11	43.47± 0.21	29.92± 0.15	29.29± 0.21
PUFA	C16:3	0.98± 0.05	0.75± 0.02	0.64± 0.01	1.12± 0.09	0.66± 0.06	0.84± 0.11	2.01± 0.08	1.60± 0.03
	C18:2	3.86± 0.02	3.54± 0.01	5.89± 0.04	4.11± 0.09	3.55± 0.01	2.76± 0.02	1.32± 0.01	2.68± 0.07
	C18:3	0.79± 0.09	0.25± 0.06	1.19± 0.1	1.59± 0.12	0.91± 0.04	1.60± 0.05	1.87± 0.04	0.47± 0.01
	C20:4	0.86± 0.09	1.43± 0.05	0.78± 0.07	0.49± 0.06	0.95± 0.01	0.67± 0.03	1.65± 0.02	0.47± 0.01
	C20:5	6.52± 0.07	10.65± 0.21	0.51± 0.03	3.16± 0.07	10.50± 0.20	7.99± 0.06	8.58± 0.09	11.29± 0.11
	C22:5	0.38± 0.01	0.47± 0.02	0.44± 0.01	0.42± 0.03	0.55± 0.01	0.34± 0.01	0.35± 0.02	0.44± 0.01

	C22:6	7.92± 0.03	8.28± 0.02	6.62± 0.04	7.44± 0.03	6.00± 0.02	6.88± 0.03	11.13± 0.01	8.06± 0.01
	ω3	14.82	19.41	7.58	11.02	17.06	15.21	20.07	19.8
	ω6	5.52	5.23	7.87	6.2	5.42	5.03	4.84	3.62
	ω3/ω6	2.68	3.71	0.96	1.77	3.14	3.02	4.14	5.45
	ΣSFA	50.72	44.7	49.62	50.5	46.62	34.3	42.35	44.54
	Σ MUFA	27.94	29.9	34.27	31.14	30.23	44.6	30.72	30.42
	ΣPUFA	21.33	25.39	16.09	18.35	23.14	21.09	26.92	25.03

The ω-3 fatty acids are the most important fat fraction of the PUFAs in fish muscle. Their content varied from 7.58% and 11.02% (in spring) to 20.07 % and 19.80 % (in autumn) respectively for males and females. The PUFAs contained essentially the eicosapentaenoic (C20:5) with maximum values equal to 10.50 % in summer for males and 11.29 % in autumn for females; and the docosahexaenoic acids (C22:6) with maximum values in autumn equal to 11.13 % and 8.06 % for males and females respectively. PUFAs are also formed by other minor fatty acids such as: linoleic acid (C18:2), linolenic acid (C18:3), arachidonic acid (C20:4) and docosapentaenoic acid (C22:5). In autumn, the fish muscle presented the higher value of ω3 fatty acids for males and females. A high Σω3/Σω6 ratio of fish muscle was observed essentially in autumn (4.14 % for males and 5.45 % for females) showing the predominance of ω-3 fatty acids. The main SFA was palmitic acid (C16:0) with values varying from 20.57 in autumn to 34.90 % in spring for males and from 22.36 in summer to 34.61% in spring for females (Table 2). The MUFA fraction was predominated by oleic acid (C18:1) for males (24.12 % in winter to 31.59 % in spring for males and from 25.09 % in winter to 43.47 % in summer).

Mineral composition

Mineral composition (Fe, Zn, K, Mg, Na and Ca) in muscle of *Zosterisessor ophiocephalus* are shown in Table 3. The highest mineral content was observed in summer (176.92 mg/100 g) and in spring (260.56 mg/100 g) for males and females, respectively. Interestingly, the relative abundance of minerals was Ca > K>Na >Mg> Fe> Zn. The highest Ca content was found 74.13 mg/100 g in summer for males and 83.04 mg/100 g in autumn for females. However, K content varied from 37.02 mg/100 g (in winter) to 54.47 mg/100 g (in summer) for males; and between 33.73 mg/100 g (in summer) and 117.69 mg/100 g (in spring) for females. Fe contents varied between 0.06 mg/100 g (in spring found for males) and 0.48 mg/100 g (in winter obtained for males). Mg had the highest values in summer for males (17.48 mg/100 g) and in spring (14.34 mg/100 g) for females. The Na element showed the highest values for males in summer (30.22 mg/100 g) and for females in spring (48.62 mg/100 g). Generally, the interaction season and sex illustrated significant effect on Fe, Zn, Na, Ca, K and Mg variations (p values < 10^{-3}).

Table 3. Seasonal variation of mineral elements content in the muscle of *Zosterisessor ophiocephalus*) Mean values of 3 samples ± SE; Values in the same row with different letters are significantly different (p<0.05).

Season	Sex	Fe	Zn	K	Mg	Na	Ca
Winter	Male	0.48± 0.001 d	0.12± 0.003 c	37.02± 0.04a	5.23± 0.02 b	18.23± 0.02b	68.21± 0.08c
	Female	0.46 ± 0.02 d	0.13± 0.004 b	35.66± 0.01b	2.68± 0.01a	13.03± 0.01a	42.29± 0.01a
Spring	Male	0.06± 0.004 a	0.09± 0.001b	51.64± 0.05C	9.97± 0.01c	20.49± 0.05c	36.98± 0.06a
	Female	0.14± 0.009 b	0.02± 0.002 a	117.69± 0.01a	14.34± 0.02 d	48.62± 0.02d	79.74± 0.06a
Summer	Male	0.21± 0.003 b	0.39± 0.01 d	54.47± 0.01d	17.48± 0.008d	30.22± 0.004d	74.13± 0.03d
	Female	0.10± 0.006 a	0.15± 0.0004c	33.73± 0.01d	6.92± 0.01c	19.94± 0.03 b	52.59± 0.002b
Autumn	Male	0.24± 0.001c	0.06± 0.004 a	37.57± 0.03 b	4.33± 0.13 a	17.75± 0.004 a	61.18± 0.01b
	Female	0.38± 0.004 c	0.18± 0.0005d	52.1± 0.07 c	5.72± 0.02 b	30.45± 0.24c	83.04± 0.03d

DISCUSSION

From this study, dedicated to specimens of *Zosterisessor ophiocephalus* caught from Gabes gulf area (Tunisia), it can be conclude that the general chemical composition undergoes little fluctuation in response to various factors. Moisture was the major constituent in all parts of muscle and the highest value was found in January for females and July for males (>80 g 100 g). As reported by diverse studies [22], moisture content varied widely with seasons but in this fish, it varied slightly. Heterogeneous distribution of protein content especially in male species was also observed. The gonadic maturation and spawning periods extending between February and June corresponded to fish muscle having a medium nutritional value (15.70 <protein in g/100 g< 18.30; 0.66 < fat in g/100 g < 0.91 and 1.11 < ash in g/100 g < 1.58 for males; and 16.69 < protein in g/100 g < 18.20; 0.74 < fat in g/100 g < 1.02 and 1.30 < ash in g/100 g <1.60 for females) (Figure 1). Before the gonadic maturation (from December to January) the fish present a low nutritional value. It was reported [23] that the thin fish, belonging to the Gadus type, store some fat reserves in their liver to be ready for reproduction. In this period the fish stocked their reserves of fat in liver (in January, fat content represent 44.04 % in liver, 7.76 % in gonads and 4.35 % in viscera; and protein content represent 26.61 % in gonads, 11.67 % in liver and 17.96 % in viscera). After the spawning period from June to November) the fish samples showed a medium nutritional value (15.51 < protein in g/ 100 g < 21.33; 0.60 < fat in g/ 100 g< 1.98 and 1.58 < ash in g/ 100 g < 1.97 for males; and 17.35 < protein in g/ 100 g < 18.20; 9.45 < fat in g/ 100 g < 1.33 and 1.33 < ash in g/ 100 g <2.02 for females). However, based on protein and fat contents, *Zosterisessor ophiocephalus* can be considered as a lean fish quality with lower nutritional values over the year (75.70 Kcal /100 g of fresh fish for males and 77.44 Kcal /100 g of fresh fish for females annually) (Figure 2). Over the year, both males and females have lower nutritional values inferior to 103.20 kg cal/ 100g. Grass goby is considered as a lean fish (<1 % fat) [24] and fat is stored in the liver [23]. In this perspective, it was reported that muscles of little active species are poor in fats as compared with those in species which are characterized by higher functional activity [25]. Low fat content (2.13/100 g) was observed in the muscle tissue of the same fish from the sea of Southern Italy (Mar Grande Sea) [26], but our in results is more lower. There are several factors that may contribute to the marked differences observed in the lipid profiles of fish such as species, season, geographical origin, diet, age, and reproductive status [27,28].

Marine food is able to provide the human organism with cellular maintenance and essential building materials. The muscle of thin fish, such as the goby, has an energy value slightly lower than that of beef but it is more digestible [29]. The low content of conjunctive tissue and the short length of muscle fibers facilitate the hydrolysis of fish proteins. Consequently the examined fish could be recommended for human nutrition. The grass goby is the thinnest fish and it could be recommended to people being on a light diet.

In the same way, ash contents varied significantly as a function of the interaction of fish sex and seasons with higher values observed in May and December for males and females, respectively. Furthermore, ecological and physiological peculiarities of fishes significantly affect the lipid fatty acids composition. The high amounts of saturated and monounsaturated fatty acids in *Zosterisessor ophiocephalus* muscles are almost in agreement with data obtained from other studies. Generally, SFAs and MUFAs are abundant in fish from warm or temperate regions, compared to PUFAs which show high levels in fish from cold regions [30]. The dominance of SAFAs was mainly due to the high value of palmitic acid, contributing approximately to 70% of the total SAFAs content in the examined fish. It seems that the fish diet contain higher SFA and MUFA, but deficient in PUFA [31,32]. Palmitic acid (C16:0) was the main fatty acid contributing of the total SFA content of lipid for all *Zosterisessor ophiocephalus* samples. This result is in good agreement with those reported in previous research [26,33,34]. It is also important to mention that the $\Sigma\omega 3/\Sigma\omega 6$ ratio is medium in the Tunisian *Zosterisessor ophiocephalus*. It was demonstrated that an increase of this ratio in the human dietary help to reduce cancer risk and to prevent coronary heart disease, shock syndrome and cardiomyopathy [35,36]. Thus, this ratio is a good index to compare fish oil relative nutritional values [37]. Interestingly, the total ω-3 fatty acid content (7.58-20.07 %) was at acceptable levels compared to the marine fish oil from the Mediterranean, Mar Grande Sea, *Zosterisessor ophiocephalus* (22.90 %) [27]. Therefore, *Zosterisessor ophiocephalus* seems to be a good source of ω–3 fatty acids recognized for their health benefits. The percentages of these ω-3 PUFAs in fish muscle are dependent on diet [38] and their variations might be related to changes in the nutritional habits of the fish [39]. EPA and DHA fatty acids have extremely beneficial properties, in particularly, in the prevention of human coronary artery disease [40]. Although fish are the most important dietary source of highly unsaturated fatty acids, especially EPA and DHA, they are not capable of synthesising long-chain ω-3 PUFAs. Fish feed on microorganisms (such as algae) or on smaller fish that consume PUFA-synthesising micro-organisms, thus acquiring long-chain ω-3 PUFAs [28]. Among the ω-6 fatty acids, *Zosterisessor ophiocephalus* accumulated arachidonic acid (C20:4) in summer (2.00 % for males and 2.15 % for females) which is a precursor for prostaglandin and thromboxane biosynthesis. It influences blood clot formation and its attachment to the endothelial tissue during wound healing [41].

Concerning the mineral content of *Zosterisessor ophiocephalus*, among the essential elements analyzed, Ca, K, Na and Mg were found to be the most abundant, whereas Zn and Fe were presented at very low levels. The most important elements are essential to cellular metabolism and commonly found at high concentrations in biological tissues [42]. Element with lower levels (Zn and Fe) are widely known to be present in enzyme active centers that are responsible for the development of important functions in all animals. Thus, marine-derived foods can serve as a good source of essential elements [43,44]. In fact, marine organisms absorb minerals from their diet and the surrounding water and deposit them in their skeletal tissues and organs. As reported for protein and fat, mineral content varied with seasons. Generally, the concentration of minerals in fish is influenced by a number of factors such (species, size, dark/white muscle, age, sex, sexual maturity, area of catch, food source, water chemistry, salinity, temperature and contaminants, etc.) [45,46,47]. Furthermore, it has been reported that intrinsic factors such as growth (size, weight), age, sex, sexual maturity, fish mobility physiology and stress influence the accumulation of trace metals in marine organisms [48].

CONCLUSION

The study of the seasonal variation of the composition of *Zosterisessor ophiocephalus*, from the Gabes Gulf (Tunisia) is important and useful in commercial exploitation as flower fish. Grass goby have a lower commercial quality and can be processed into fish flower. The flower is even better than lean fish [49]. Generally, *Zosterisessor ophiocephalus* muscle contains a low fat and high protein contents accompanied by a high moisture level. The nutritional quality of *Zosterisessor* *ophiocephalus* indicates its lower energetic and nutritional values over the year. The significant seasonal differences observed in the mineral contents are mainly related to diet and environmental factors.

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