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Biochemical composition, nutritional value, and socio-economic impacts of the invasive crab *Callinectes sapidus* Rathbun, 1896 in central Mediterranean Sea

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Abstract

The Atlantic crab *Callinectes sapidus* was recently recorded in Tunisia and presents an invasive behavior. This study aims to evaluate its socio-economic impacts on small-scale fisheries and to analyze variations in chemical composition, fatty acids profile, and nutritive value according to sex and edible tissues. Face-to-face surveys revealed a decline in fishermen's income from 15% to as much as 70% related to damages on fishing nets and catches. Captures of *C. sapidus* are increasing compared to the beginning of its occurrence with more than 10 kg/fishing day and low landing prices (0.8-1 US $/kg). Muscles yield of *Callinectes sapidus* ranged between 36.07 ± 2.84% and 42.83 ± 6.53%, respectively, for females and males. All the analyzed tissues contained high protein contents (> 23%) and particularly the cephalothorax muscles which attained 27.05 ± 0.16%. Fats in muscles range between 2% and 3.69% of the wet weight of the crab. Since total lipid content is below 5%, this new exotic food can be recommended in low fat diets. The fatty acid profile was dominated by the polyunsaturated fatty acids (PUFA) for both sexes and all the analyzed tissues. Eicosapentaenoic *acid*, docosahexaenoic *acid,* and arachidonic acid were the most abundant PUFA in all tissues ranging from 9.31% to 15.64%, from 8.74% to 13.78%, and between 6.81% and 9.21% for each acid. All the nutritional indexes of lipids indicated that this decapod could be beneficial for human health.

Keywords: Non-indigenous marine species; Proximate composition; Fatty acids; Nutritional indexes of lipids; Food value chain.

Introduction

Biological invasions have been considered worldwide as a major driver of change in Mediterranean marine biodiversity (Azzurro *et al.,* 2019) and consumer behavior (Nuñez & Simberloff, 2005). In fact, endemic species and traditional marine resources and stocks have decreased and been replaced by Alien Invasive Species (AIS). Firstly, AIS were perceived as a disaster due to their severe economic impacts on fisheries, aquaculture, tourism, and human health (Piras *et al.,* 2019). Nevertheless, edible alien species can represent an opportunity for local economies (as a new food resource) and not only a threat to livelihoods (Nuñez *et al.*, 2012). Indeed, the consumption of AIS such as *Macrobrachium nipponense* (De Haan, 1849 [in De Haan, 1833-1850]), *Metapenaeus monoceros* (Fabricius, 1798), *Penaeus aztecus* Ives, 1891, and the lionfish *Pterois volitans* (Linnaeus, 1758) may represent a good opportunity to improve the socio-economic situation of locals, especially fishermen (Limam *et al.,* 2014; Lavajoo *et al.,*2018; Castro-González *et al.,* 2019; Kampouris *et al.,* 2021).

Crustacean decapods are among the best-studied marine alien species in Tunisia (Bejaoui *et al.,* 2017; Rjiba-Bahri et *al.*, 2019; Khamassi *et al.*, 2019; Chaffai *et al.*, 2020; Shaeik *et al.,* 2021). Alien portunid crabs are regularly caught and landed by small-scale fisheries in Tunisia since 2015 for *Portunus segnis (P. segnis)* (Forskål, 1775) and later for the Atlantic crab *Callinectes sapidus (C. sapidus)* Rathbun, 1896 (Ben Souissi *et al.,* 2017; Katsanevakis *et al.*, 2020). Despite the high commercial value of these species (Kücükgülmez & Çelik, 2008; Zotti *et al.*, 2016; Bejaoui *et al.*, 2017), few studies concern their biological traits and chemical composition in the southern coasts of the Mediterranean Sea.

Callinectes sapidus is eurythermal and euryhaline crab and can inhabit estuaries, lagoons, and other coastal habitats (Taybi & Mabrouki, 2020). In addition, it exhibits high fecundity and strong swimming capacities. It is considered as an opportunistic and aggressive predator and displays scavenging and cannibalistic behaviors (Kampouris *et al.*, 2019). Such characteristics have contributed to its establishment and expansion of its distribution range in the Mediterranean Sea since its first record in 1948 in the Northern Adriatic Sea (Galil et *al*., 2002). *Callinectes sapidus* was firstly introduced in the south-eastern Mediterranean Sea in 2017 in Morocco (Chartosia et *al.*, 2018), and was then introduced in Tunisia (Ben Souissi et *al*., 2017) and Algeria in 2018 (Benabdi et *al*., 2019). According to Katsanevakis et *al.* (2014), *C. sapidus* is one of the 100 "worst invasive" alien marine species in the Mediterranean with high impact mainly on ecosystem biodiversity and artisanal fishing activities.

Despite the 2290 km of coastline, seafood consumption remains modest in Tunisia with values of 11.4 kg / year / inhabitant according to FAO (2014) and is limited to coastal towns. Before the development of marketing and distribution circuits for fisheries products as well as cold chains during the 1980s, non-coastal regions consumed salted and dried fish, mainly sardines and anchovies. As usual in North African countries, the culinary traditions in Tunisia are rather oriented towards the consumption of terrestrial animals, especially lamb and camel meats. Even in coastal areas, the range of consumed species was restrained to commercial fishes and cuttlefish (FAO, 2014). Other products such as shellfish and crustaceans (mussel, oyster, and shrimp) are mainly exported or used in local restaurants and hotels, except for the inhabitants of the Kerkennah Islands who have a tradition of consuming native crabs such as *Carcinus aestuarii* Nardo, 1847.

For this purpose, nutritive value characterization is fundamental to encourage and raise awareness among Tunisian consumers of the nutritional benefits of this new food bioresource that is rich in proteins and essential fatty acids, as well as to facilitate the processing and marketing of *C. sapidus* like the Lessepsian crab *P. segnis* (Khamassi *et al.,* 2019). Since 2017, more than 28 processing units and export companies have been implemented in Tunisia and crab exports increased 100 times between 2015 and 2019 to more than 20 destinations all over the world (GIPP, 2019). The exported quantities reached 3500 tons for more than 12 million euros in 2019 (export price is between 2.5 and 4 €/kg depending on products) (GIPP, 2019).

In light of these considerations, this paper is the first to report the socio-economic impacts of *C. sapidus* on Tunisian small-scale fisheries and to provide nutritive values. For this, meat yield, proximate composition, fatty acids profiles, and nutritional indexes of lipids were determined for all edible tissues.

Materials and Methods

Study area and socio-economic impacts analysis of C. sapidus *on local fisheries*

Local Ecological Knowledge (LEK) is representing a growing area of opportunity and a complementary method for scientific research (Azzurro *et al.*, 2011). To ovoid misidentification between the two species of alien portunids, fresh crab samples were showed to local fishermen. A representative sample of face-to-face interviews was conducted with experienced Tunisian fishermen (of more than 10 years) to assess socio-economic impacts of *C. sapidus* in the most affected areas in north-eastern coasts of Tunisia (Central Mediterranean Sea). Surveys were carried out on three areas based on the degree of blue crab contamination. Weakly affected (Kalaat Landalous; 37.0523° N, 10.1137°E), moderately affected (Tunis southern lagoon; 36.4738° N, 10.1522° E), and severely impacted (Ghar el Melh; 37. 0806° N, 10.1422° E) (Fig. 1).

The data was collected from fishermen based on their personal declaration. The interview took approximate-

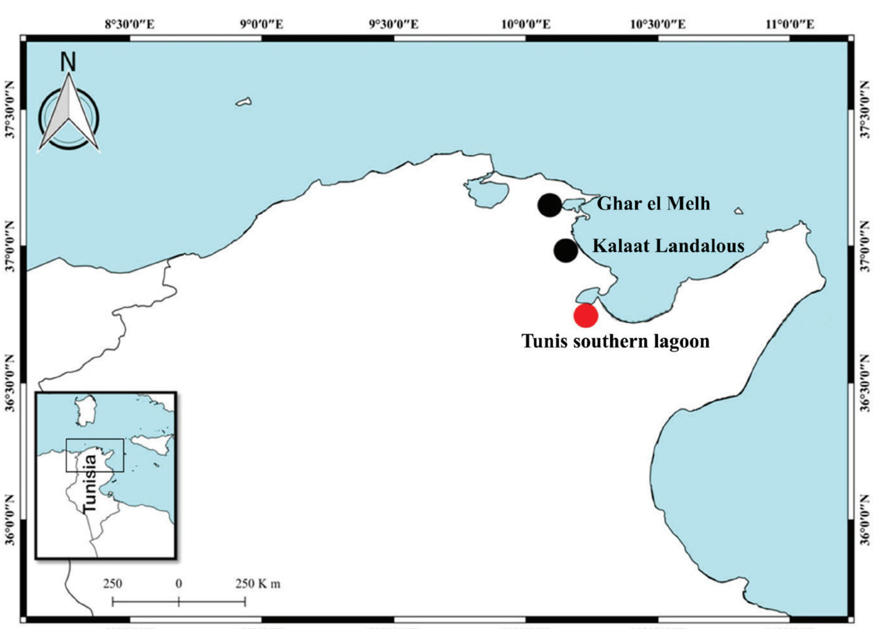

Fig. 1: Study areas (red circle indicates sampling site for biochemical analysis).

ly 30 minutes to complete and was structured into three main sections: socio-demographics of fishermen, characteristics of fishing activity, and economic impacts caused by *C. sapidus* (losses in fishing gears, catch yields, and fish damages; Rjiba-Bahri *et al.,* 2019). Data from these surveys were coded, entered into an Excel database, and then analyzed.

Sampling protocol and determination of crab meat yield

Specimens of *C. sapidus* were collected from the southern lagoon of Tunis (north-east of Tunisia) during July 2021 with fyke nets of 18 mm mesh size. Samples were then transferred alive to the laboratory to be measured and classified into males and females. Morphometric measurements include carapace width (CW, mm), carapace length (CL, mm), and the total wet weight of the crab (WW, g) (Rjiba-Bahri *et al.*, 2019). Adult crabs were euthanized by thermal shock (-20 °C for 10 min) and divided randomly into three homogeneous groups. After that, hepatopancreas and muscles from the thoracic sterna, claws (chelipeds), and locomotory pereiopods of each group were hand-picked and each was blended separately to homogenize them (Kücükgülmez *et al.*, 2006; Zotti *et al.*, 2016). Each tissue was subsequently weighed to calculate yields (1) and then stored at -20°C for further biochemical analysis.

$$\text{Tissue yield (\%)} = 100 \times (TW / WW) \quad (1)$$

TW: tissue wet weight (g); WW: total crab wet weight (g)

Proximate composition analysis

Moisture content was determined according to AOAC (2005). Protein content was determined using the Bradford procedure (Bradford, 1976). Total lipids were extracted from analyzed tissues (muscles and hepatopancreas) according to Folch *et al.* (1957). The energy value of the crab was determined based on the percentage of biochemical composition using the following factors: proteins, 4.27 kcal g^{-1} wet weight; lipids, 9.02 kcal g^{-1} wet weight where 1 kcal = 4.184 kJ (FAO, 1989).

Fatty acid profile

After lipid extraction, acid methyl esters were recovered using the Metcalfe *et al.* (1966) methylation method in which boron trifluoride BF_3 is used with methanol (Morrison & Smith, 1964; Moss *et al.*, 1974). For the quantitative analysis of each fatty acid, nonadecanoic acid methyl ester C19:0 Me (Sigma Chemical Co. Ltd) was used as an internal standard. Sample compositions were investigated by HP5890-series II gas chromatograph (Agilent Technologies, California, USA) equipped with flame Ionisation Detector (FID) under the following conditions: the fused silica, capillary column, polar HP Innovax (column: 30 m, 0.25 mm ID, film thickness). The oven temperature was held at 50°C for 1 min then programmed at rate of 5°C/min to 240°C and held isothermal for 4 min. The carrier gas was nitrogen at a flow rate (1.2 ml min^{-1}). The injector and detector temperatures were 250°C and 280°C, respectively. The volume injected was 0.1 µl of the solution diluted in hexane. The total time of the chromatograph was 30 min (Mnari *et al.*, 2007; Bouhlel *et al.*, 2009).

The identification of fatty acid methyl esters was performed by external standards (Supelco ®, ISO9001-QRS-255) submitted to the same processes of manipulation as the biological samples analyzed (Bouhlel *et al.*, 2009). The values of fatty acids are presented as area percentage of total fatty acids.

Nutritional quality indexes of lipids

Quality indexes of lipids were calculated based on fatty acid composition.

-*Atherogenicity index-AI:*

$$AI = ((C12{:}0 + (4 \times C14{:}0) + (C16{:}0)) / ((\sum n6 + \sum n3 + \sum MUFA))$$

(Ulbricht & Southgate, 1991)

-*Thrombogenicity index-TI:*

$$TI = ((C14{:}0 + C16{:}0 + C18{:}0)) / ((0.5 \times \sum MUFA) + (0.5 \times \sum n6) + (3 \times \sum n3) + (\sum n3 / \sum n6))$$

(Ulbricht & Southgate, 1991)

- *The index of hypocholesterolemic/hypercholesterolemic fatty acids –HH*:

$$HH = (C18{:}1n9 + C18{:}2n6 + C18{:}3n3 + C20{:}4n6 + C20{:}5n3 + C22{:}5n3 + C22{:}6n3)/(C14{:}0 + C16{:}0)$$

(Fernandes *et al.,* 2014).

-*The ratio PUFA/SFA* refers to the ratio between polyunsaturated (PUFA) and saturated fatty acids (SFA).

-*The ratio of n3/n6*: Σ n3 PUFA/Σ n6 PUFA

Statistical analysis

A one-way ANOVA was performed after normal distribution data analysis using the Shapiro-Wilk test and the homogeneity of variance was confirmed by the Levene test. Duncan's multiple range test was assessed to separate differences among means. All statistical analyses were tested at the 0.05 level of probability with the software Statistical Analysis System (SAS 9.1.3, 2002-2003, Institute Inc., Cary, NC, USA).

Results

Socio-economic impacts of the invasive crab **C. sapidus** *on local fisheries*

Table 1 summarizes the socio-demographic characteristics of interviewed fishermen and highlights a relatively young population involved in artisanal fishing activity, with a level of education not exceeding primary school in 70% of cases. More than 70% of the respondents have

Table 1. Socio-demographic characteristics of fishermen.

%	Variable	Category
6	20-39	
56	39-59	**Age (years)**
38	> 59	
70	Primary school	
28	Secondary school	**Level of education**
2	University	
28	< 3	
60	3-6	**Household population**
12	> 6	
16	1-20	**Fishing experience (years)**
84	> 20	
98	Permanent	**Fishing activity**
2	Seasonal	

at least 20 years of fishing experience and three persons in charge have fishing activity as a unique income. All of respondents had unambiguously distinguished *C. sapidus* from *P. segnis* already established in Ghar el Melh. More than 80% of the fishermen confirmed the presence of the Atlantic blue crab over all the fishing areas at depths not exceeding ten meters which confirms the euryhaline character of this species.

Callinectes sapidus catches are increasing (more than 5 kg/ fishing day) (Table 2). In fact, 75% and 100% of the respondents declared more than 5 kg of *C. sapidus* per fishing day respectively in Ghar el Melh and Tunis southern lagoon. However, in Kalaat Landalous, 85% of fishermen captured less than 5 kg for the same species and fishing effort (Table 2). Additionally, Ghar el Melh is considered as a sinister zone invaded by blue crabs where 100% of fishermen asserted a decrease in their mean annual income between 15% and 70%. Only 20% of the interviewees from Kalaat Landlous was not yet affected by crab damages on their fishing gear (Table 2).

Damages concerned the clogging and ripping of both trammel and gillnet (Fig. 2B), which required their renewal for 70% of the interviewees. In addition, the crab spines injured the fishermen when they removed crabs from trammel nets (Fig. 2C). As well as damages to fishing gear, fishermen complained about crab predation on their catches (Table 2), which comprised various high commercial value species, namely *Sepia officinalis* Linnaeus, 1758, *Sparus aurata* Linnaeus, 1758*, Anguilla anguilla* Linnaeus, 1758, *Solea senegalensis* Kaup, 1858, and *Diplodus sp.* (Fig. 2A). The mutilated catches must be discarded, thereby inducing a decrease in production and fishery value.

Meat yield of C. sapidus

Adult males and females were measured and weighed (Fig. 3). The mean carapace width CW, carapace length CL, and total weight TW of adult specimens were, respectively, 135.38 ± 10.34 mm, 59.75 ± 5.48 mm, and 167.41 ± 34.37 g for females and 134.51 ±17.09 mm, 62.34 ± 7.17 mm, and 185.19 ± 65.15 g for males. Figure 4 shows the texture of the different edible muscles in *C. sapidus,* namely those of chelipeds (ChM), cephalothorax (ThM), and locomotion pereiopods (LPeM). All tissues yield were higher for male crabs (Fig. 5). Total muscles yields represent 36.07 ± 2.8% and 42.83 ± 6.5% respectively for females and males. The thorax muscles yield was the highest, averaging 18.96 ± 2.26% and 16.06 ± 1.89% respectively for males and females, followed by chelipeds and locomotion pereiopod muscles yield (17.65

Table 2. Effects of *C. sapidus* on mean annual income, fishing gear, and catches.

Percentage of interviewed fishermen/ locality				
Kalaat Landlous (river mouth)	**Tunis Southern Lagoon (lagoon)**	**Ghar El Melh (sea)**		
85	0	25	< 5 kg/fishing day	**Crab catches**
15	100	75	> 5 kg/fishing day	
50	57	0	No effect	**Decrease in mean annual income**
13	43	70	< 50%	
37	0	30	> 50%	
20	0	0	No effect	**Damage to fishing gear**
80	100	100	Clogging & ripping	
0	0	0	No damage	
12.5	0	0	Injured	**Damage to catches**
87.5	100	100	Mutilated	

Fig. 2: Damage caused by the blue crab (scale bar = 2 cm) A: on catches, B: on nets, C: on fishermen.

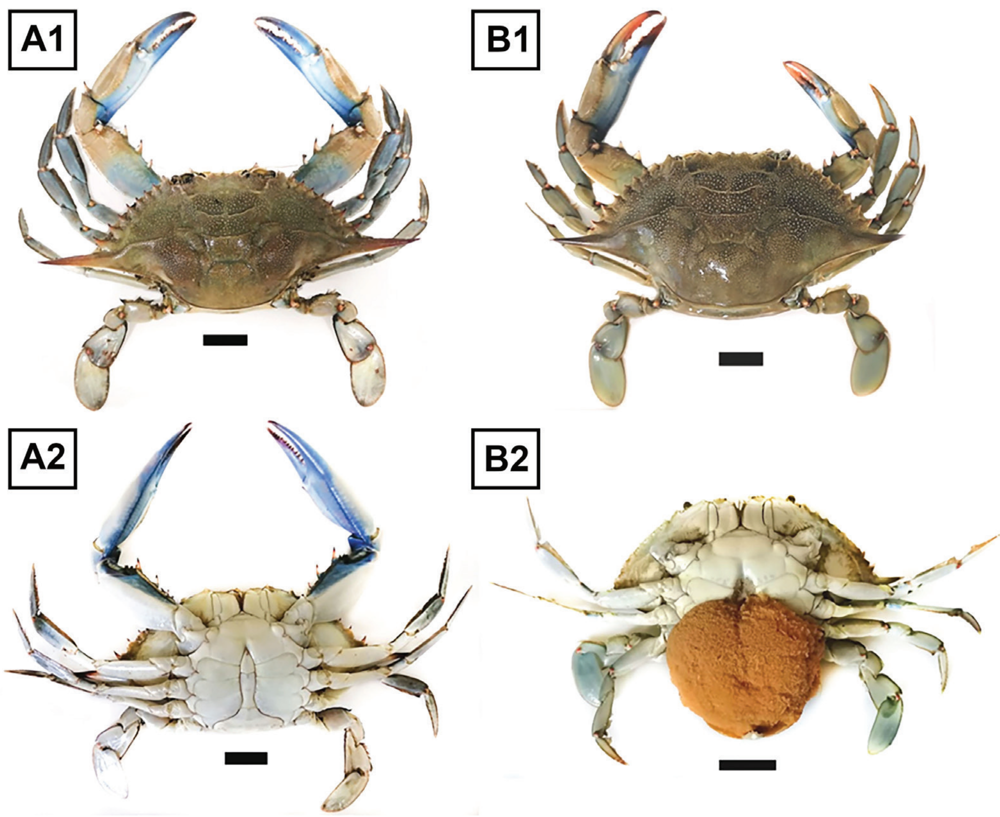

Fig. 3: Dorsal and ventral views of male (A1, A2) and berried female (B1, B2) of *Callinectes sapidus* collected from Tunis southern lagoon of (scale bars = 2 cm).

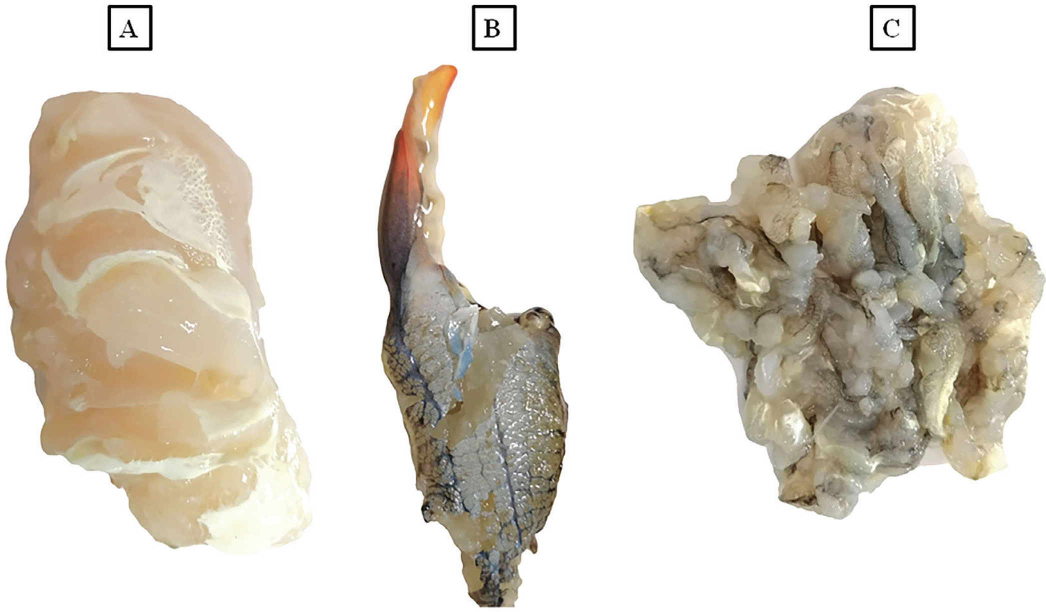

Fig. 4: Muscles of *C. sapidus* A: Cephalothorax muscles; B: Cheliped muscles; C: locomotory pereiopods muscles.

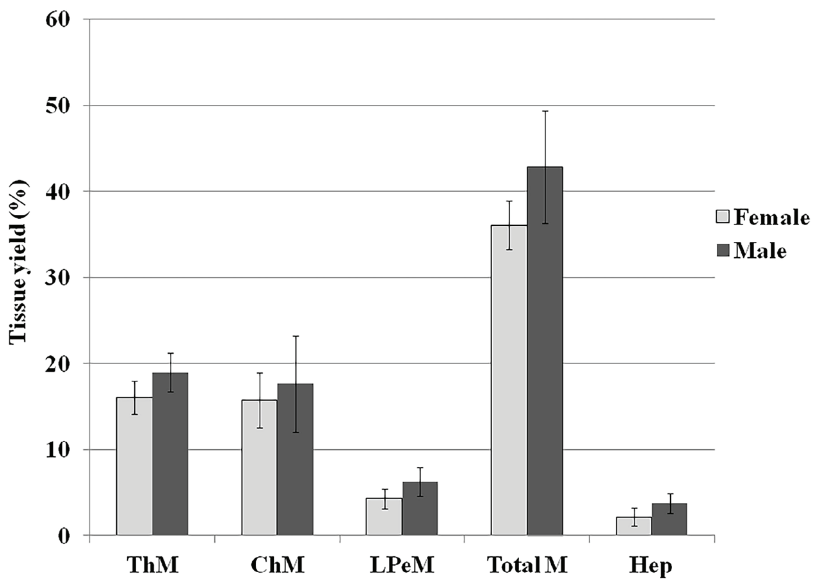

Fig. 5: Muscle and hepatopancreas yields of *C. sapidus.* ChM = cheliped muscles, ThM = cephalothoracic muscles, LPeM = locomotory pereiopod muscles, Total M = total muscles, Hep = Hepatopancreas.

± 5.57% and 6.23 ± 1.67% for males and 15.73 ± 3.16% and 4.29 ± 1.14% for females). For locomotion pereiopods, flesh content was lower than other body structures (4.29 ± 1.14 and 6.23 ± 1.67 respectively for females and males); therefore, they were not considered in the biochemical analysis.

Proximate composition

Proximate composition of analyzed tissues for both crab sexes is presented in Table 3. It varies significantly with edible tissue type and sex ($P < 0.05$). Results showed that moisture was significantly higher in muscles. For protein concentration, no sex difference was reported in the thoracic muscles or the hepatopancreas, unlike the chelipeds (23.71 ± 0.19% and 25.77 ± 0.14%, respectively, for females and males) (Table 3). However, a significant difference between protein content in muscles and brown meat was observed, with higher values in the thoracic muscles (ranging between 26.56 ± 0.24% and 27.05 ± 0.16%, respectively for females and males). Otherwise, total lipid content was the highest in the hepatopancreas, reaching 12.19 ± 2.49% but not exceeding 3.69 ± 1.39% in muscles tissues. Thus, the energy value was significantly higher in the hepatopancreas ($P < 0.05$) (ranging between 221.5 ± 1.89 and 262.51 ± 23.5 kcal/100 g).

Table 3. Proximate composition of *C. sapidus* (% wet weight)[1].

		Muscles		Hepatopancreas	SEM	*P* > F
		Cephalothorax	Chelipeds			
Moisture	M	67.4 ± 0.6[a]	68.7 ± 0.9[a]	60 ± 2.6[b]	1.36	0.006
	F	68.8 ± 0.3[a]	70.3 ± 1.6[a]	63.5 ± 0.3[b]	0.798	0.002
Fat	M	2.91 ± 0.7[b]	2.86 ± 0.94[b]	12.19 ± 2.49[a]	1.37	0.004
	F	2 ± 0.06[b]	3.69 ± 1.39[b]	7.85 ± 0.19[a]	0.702	0.002
Protein	M	27.05 ± 0.16[a]	25.77 ± 0.14[b*]	26.07 ± 0.08[b]	0.108	0.0004
	F	26.56 ± 0.24[a]	23.71 ± 0.19[b*]	26.07 ± 0.02[a]	0.152	< 0.0001
Energy value [2]	M	180.36 ± 6.95[b]	172.65 ± 8.82[b]	262.51 ± 23.5[a]	12.81	0.004
	F	168.92 ± 1.94[b]	168.84 ± 14.08[b]	221.5 ± 1.89[a]	6.901	0.002

[1] Data are expressed as mean ± SD (n = 3); [2] Data are expressed as kcal/100g wet weight. Different letters in the same line indicate significant differences between the analyzed tissues. An asterisk * indicates significant difference between sexes.

Fatty acids composition

Fatty acids composition of the different crab edible parts is summarized in Table 4. It was dominated by polyunsaturated fatty acids (PUFA) for both sexes (PUFA/SFA > 1). Muscles contained significantly higher amounts of PUFA ($P < 0.05$) (Table 4). Among saturated fatty acids (SFA), palmitic and stearic acids (C16:0; C18:0) were predominant (ranging from 4% to 16%) in all analyzed samples with higher values in the hepatopancreas. Significant sex and edible tissue type differences ($P < 0.05$) in SFA were observed; higher SFA concentrations are recorded in male hepatopancreas (35.76%) (Table 4). Furthermore, monounsaturated fatty acids (MUFA) were higher in females and in their hepatopancreas tissue ($P < 0.05$). In fact, oleic acid (C18:1 n9) was the major MUFA in all tissues type (more than 15% in female claw muscles), followed by palmitoleic acid (C16:1 n7; ranging between 2.81±0.33% and 10.87±0.12%) and octadecenoic acid (C18:1n7; ranging between 2.31±0.03% and 2.95±0.29%) (Table 4). Significant differences were observed between the sexes and the analyzed tissues for some MUFA (Table 4). Female thoracic muscles contained higher amounts of C16:1 n7, C18:1 n7, and female hepatopancreas comprised the highest content of C16:1 n7, C18:1 n9, C17:1, and C16:1 n9 ($P < 0.05$). Moreover, the total PUFA percentage ranged between 36.45% and 43.64% for females and between 37.83% and 44.15% for males. Essential fatty acids, namely eicosapentaenoic *acid* (*EPA*, C20:5, n3, ranged from 9.31% to 15.64%), docosahexaenoic *acid* (DHA, C22:6 n3, ranging between 8.74% and 13.78%), and arachidonic acid (C20:4 n6, ranging between 6.81% and 9.21%) were the most abundant fatty acids in all analyzed tissues. However, the other PUFA (C22:5 n3 and C20:4 n3) did not exceeded 0.35% of the total fatty acids (Table 4). Significant differences between sexes were observed for most PUFA with higher amounts in male tissues ($P < 0.05$), except for *EPA* and DHA (Table 4). In addition, muscles contained significantly higher PUFA contents than did the hepatopancreas of both sexes (ranging from 6% to 16% and between 8% and 11%, respectively, for muscles and hepatopancreas) ($P < 0.05$).

Nutritional quality index of lipids

To estimate the nutritional quality of lipids in *C. sapidus*, some indexes and ratios have been calculated and are presented in Table 5. All analyzed samples had n3/n6 PUFA and PUFA/SFA ratios (respectively from 1.74 to 2.41 and between 1.06 and 1.44) that greatly exceeded recommended values. They were significantly higher in muscles ($P < 0.05$) (Table 5). Moreover, atherogenic and thrombogenic indices (AI and TI) determination is necessary to evaluate the susceptibility of ingested fat from marine products to influence the risk of coronary heart disease. In the present study, AI and TI values for all analyzed samples were considerably below 1 (between 0.29 and 0.38) with no significant difference for TI (Table 5). The obtained cholesterolemic indexes (H/H) were significantly higher in muscles of both sexes ($P < 0.05$), averaging 2.81 for the brown meat and ranging between 3.58 and 3.8 for muscles.

Discussion

Tunisia is currently experiencing a unique phenomenon: a concomitant biological explosion by two species of blue crab, one a native from the Atlantic Ocean (*C. sapidus*) and the other an immigrant from the Red Sea (*P. segnis*). Since its first record in 2017 (Ben Souissi *et al.,* 2017), *C. sapidus* has expanded its distribution northwards (Katsanevakis *et al.,* 2020). Currently, it is recorded almost ubiquitously along northern coasts of Tunisia with an increasing exponential rate due to shipping activities (Shaeik *et al.*, 2021). Recent research suggested complementary participatory methods aiming for strong collaboration between stakeholders, namely experienced fishermen, to understand the implications of the presence of this crab (Azzurro *et al.,* 2019; Ragkousis *et al.,* 2020). Therefore, the outcomes of this study are important in highlighting the fact that the socio-economic impacts are already noticeable on small-scale fisheries in northern Tunisia in term of losses of catches and of fishing gear (Shaeik *et al.*, 2021). The main consequences were

Table 4. Fatty acids composition of *C. sapidus* (% of total fatty acids)[1].

Fatty acids	Females					Males				
	CH	CE	HEP	SEM	*P* > F	CH	CE	HEP	SEM	*P* > F
C12:0	0.85 ± 0.20^{a}	0.69 ± 0.06^{a}	0.09 ± 0.02^{b}	0.11	0.048	0.80 ± 0.2^{a}	0.43 ± 0.12^{ab}	0.13 ± 0.02^{b}	0.11	0.01
C13:0	0.88 ± 0.20	0.13 ± 0.02*	1.04 ± 0.6	NS	NS	1.08 ± 0.11^{b}	1.08 ± 0.13^{b*}	1.99 ± 0.21^{a}	0.12	0.003
C14:0	1.13 ± 0.14^{a}	0.59 ± 0.1^{b}	0.55 ± 0.16^{b}	0.11	0.017	0.94 ± 0.28	0.89 ± 0.1	0.85 ± 0.14	NS	NS
C15:0	0.42 ± 0.17	0.33 ± 0.13	0.51 ± 0.26	NS	NS	0.51 ± 0.2	0.41 ± 0.16	0.37 ± 0.08	NS	NS
C16:0	14.20 ± 0.56	14.52 ± 0.27	15.54 ± 0.08*	NS	NS	13.20 ± 0.14^{b}	13.27 ± 0.58^{b}	14.89 ± 0.09^{a*}	0.26	0.006
C17:0	3.88 ± 0.56	3.30 ± 0.48	2.66 ± 0.46	NS	NS	3.67 ± 0.48	3.05 ± 0.62	3.55 ± 0.62	NS	NS
C18:0	6.48 ± 0.12^{a}	6.50 ± 0.1^{a*}	4.79 ± 0.03^{b*}	0.08	< 0.0001	6.25 ± 0.01^{c}	8.32 ± 0.1^{a*}	7.54 ± 0.28^{b*}	0.14	0.0001
C20:0	1.34 ± 0.06^{b}	1.28 ± 0.07^{b}	1.66 ± 0.03^{a*}	0.05	0.004	1.41 ± 0.12	1.40 ± 0.19	1.14 ± 0.16*	NS	NS
C21:0	0.32 ± 0.05	0.37 ± 0.01	0.34 ± 0.01	NS	NS	0.56 ± 0.16	0.61 ± 0.28	0.36 ± 0.07	NS	NS
C22:0	0.31 ± 0.00^{b*}	0.38 ± 0.02^{a}	0.40 ± 0.02^{a}	0.01	0.0158	0.43 ± 0.02*	0.38 ± 0.08	0.44 ± 0.03	NS	NS
C23:0	0.39 ± 0.04	0.38 ± 0.03	0.43 ± 0.07*	NS	NS	0.59 ± 0.08^{b}	0.48 ± 0.08^{b}	2.09 ± 0.23^{a*}	0.13	0.0002
C24:0	1.46 ± 0.02^{c*}	1.86 ± 0.06^{b}	2.42 ± 0.06^{a}	0.05	< 0.0001	2.29 ± 0.01^{a*}	1.74 ± 0.06^{b}	2.41 ± 0.1^{a}	0.05	0.0003
C14:1n9	1.58 ± 0.01^{a*}	1.38 ± 0.01^{b}	1.31 ± 0.03^{c}	0.01	< 0.0001	1.76 ± 0.01*	1.29 ± 0.22	1.37 ± 0.2	NS	NS
C16:1n9	0.57 ± 0.03^{b*}	0.66 ± 0.04^{b}	1.12 ± 0.03^{a*}	0.03	< 0.0001	0.78 ± 0.05^{a*}	0.68 ± 0.2a^{b}	0.38 ± 0.05^{b*}	NS	NS
C16:1n7	3.40 ± 0.12^{c*}	4.97 ± 0.32^{b*}	10.87 ± 0.12^{a*}	0.22	< 0.0001	4.34 ± 0.13^{b*}	2.81 ± 0.33^{c*}	6.33 ± 0.46^{a*}	0.09	0.0003
C17:1n8	1.38 ± 0.37	1.47 ± 0.04	1.09 ± 0.32*	NS	NS	1.11 ± 0.65	1.28 ± 0.55	0.35 ± 0.09*	NS	NS
C18:1n7	2.31 ± 0.03	2.64 ± 0.06*	2.95 ± 0.29	NS	NS	2.66 ± 0.15	2.34 ± 0.06*	2.77 ± 1.39	NS	NS
C18:1n9 t	0.67 ± 0.01	0.74 ± 0.13	0.70 ± 0.04*	NS	NS	0.96 ± 0.04^{b}	0.93 ± 0.12^{b}	1.35 ± 0.04^{a*}	0.06	0.004
C18:1n9 c	15.99 ± 0.33	13.80 ± 0.41	14.66 ± 0.38*	NS	NS	13.37 ± 0.25	13.68 ± 0.68	13.55 ± 0.13*	NS	NS
C20:1n9	0.23 ± 0.01	0.22 ± 0.03	0.29 ± 0.11	NS	NS	0.40 ± 0.08	0.32 ± 0.12	0.21 ± 0.09	NS	NS
C24:1	0.23 ± 0.07	0.18 ± 0.06	0.13 ± 0.03	NS	NS	0.22 ± 0.09^{ab}	0.48 ± 0.15^{a}	0.10 ± 0.01^{b}	0.08	0.04
C18:2 t c	0.11 ± 0.01^{b*}	0.51 ± 0.03^{a*}	0.41 ± 0.18^{ab}	0.09	0.049	0.27 ± 0.06*	0.35 ± 0.06*	0.24 ± 0.08	NS	NS
C18:2 c t	0.45 ± 0.13^{b*}	0.69 ± 0.08^{ab}	0.73 ± 0.05^{a}	NS	NS	0.98 ± 0.01*	0.81 ± 0.15	0.91 ± 0.1	NS	NS
C18:2 n6	0.44 ± 0.13	0.37 ± 0.04	0.29 ± 0.01*	NS	NS	0.56 ± 0.14	0.42 ± 0.16	0.47 ± 0.07*	NS	NS
C18:2 t c	0.05 ± 0.01*	0.06 ± 0.01	0.41 ± 0.23	NS	NS	0.09 ± 0.02*	0.12 ± 0.02	0.12 ± 0.02	NS	NS
C18:2 2t	0.59 ± 0.03^{b*}	0.60 ± 0.02b	1.93 ± 0.57^{a*}	0.25	0.013	1.01 ± 0.1^{b*}	0.77 ± 0.13^{b}	4.02 ± 0.42^{a*}	0.22	< 0.0001
C18:2 c t	0.70 ± 0.00^{c*}	0.97 ± 0.01b	1.81 ± 0.04^{a*}	0.02	< 0.0001	0.99 ± 0.02^{ab*}	0.88 ± 0.13b	1.20 ± 0.12^{a*}	NS	NS
C18:3 n3	3.97 ± 0.2	3.56 ± 0.07	3.55 ± 0.01	NS	NS	4.53 ± 0.49	3.78 ± 0.16	4.35 ± 0.42	NS	NS
C20:3 n3	0.19 ± 0	0.22 ± 0.01	0.09 ± 0.01*	0.03	0.044	0.25 ± 0.08	0.20 ± 0.05	0.17 ± 0.02*	NS	NS
C18:4n3	0.31 ± 0.06*	0.26 ± 0.03	0.35 ± 0.13	NS	NS	0.60 ± 0.01^{a*}	0.66 ± 0.2^{a}	0.25 ± 0.03^{b}	0.09	0.04
C20:4n6 (ARA)	7.43 ± 0.05^{a*}	7.18 ± 0.11^{a}	6.86 ± 0.07^{b}	0.08	0.007	9.21 ± 0.16^{a*}	7.21 ± 0.46^{b}	6.81 ± 0.07^{b}	0.22	0.0005
C20:4n3	0.09 ± 0.01*	0.21 ± 0.07	0.14 ± 0.08	NS	NS	0.23 ± 0.05*	0.35 ± 0.05	0.26 ± 0.07	NS	NS
C20:5n3(EPA)	13.83 ± 0.19^{b*}	15.64 ± 0.26^{a}	11.06 ± 0.44^{c}	0.28	< 0.0001	12.58 ± 0.28^{b*}	15.20 ± 0.67^{a}	9.31 ± 0.79^{c}	0.49	0.0004
C22:5n3	0.07 ± 0.01*	0.10 ± 0.02	0.07 ± 0.01	NS	NS	0.13 ± 0.02*	0.12 ± 0.05	0.07 ± 0.01	NS	NS
C22:6n3 (DHA)	13.78 ± 0.49^{a*}	13.27 ± 0.45^{a}	8.74 ± 0.36^{b}	0.41	0.0002	11.25 ± 0.13^{b*}	13.29 ± 0.28^{a}	9.64 ± 0.47^{c}	0.25	0.0002
∑SFA (%)	31.64 ± 0.54	30.31 ± 0.33	30.43 ± 0.81	NS	NS	31.74 ± 0.15^{b}	32.04 ± 0.25^{b}	35.76 ± 0.96^{a}	0.46	0.001
∑MUFA (%)	26.35 ± 0.31^{b}	26.06 ± 1.14^{b}	33.12 ± 0.63^{a}	0.64	0.0004	25.59 ± 0.16	23.80 ± 0.25	26.41 ± 1.53	NS	NS
∑PUFA (%)	42.01 ± 0.85^{a}	43.64 ± 0.92^{a}	36.45 ± 0.22^{b}	0.59	0.0003	42.67 ± 0.22^{b}	44.15 ± 0.39^{a}	37.83 ± 0.65^{c}	0.36	< 0.0001
∑n6 (%)	7.87 ± 0.12^{a}	7.55 ± 0.19^{a}	7.15 ± 0.07^{b}	0.11	0.01	9.77 ± 0.06^{a}	7.63 ± 0.31^{b}	7.27 ± 0.12^{b}	0.14	< 0.0001
∑n3 (%)	18.41 ± 0.62^{a}	17.62 ± 0.39^{a}	12.94 ± 0.32^{b}	0.37	< 0.0001	16.99 ± 0.3^{b}	18.39 ± 0.19^{a}	14.76 ± 0.04^{c}	0.15	< 0.0001

[1] Data are expressed as mean ± SD (n = 3). Different letters in the same line indicate significant differences between the analyzed tissues for each sex. An asterisk * indicates significant differences between sexes for each tissue type. *NS* = not significant*;* *SFA* = saturated fatty acids; *MUFA* = monounsaturated; *PUFA* = polyunsaturated; *EPA* = eicosapentaenoic; *DHA* = docosahexaenoic; *ARA* = arachidonic; *CH* = Cheliped muscles; *CE* = Cephalothorax muscles; *HEP* = hepatopancreas; *SEM* = standard error of the mean.

Table 5. Lipid quality indexes in edible tissues of *C. sapidus*[1].

	Females				Males			
	CH	**CE**	**HEP**	***P* > F**	**CH**	**CE**	**HEP**	***P* > F**
w3/w6	2.34 ± 0.04[a]	2.33 ± 0.01[a]	1.81 ± 0.03[b]	< 0.0001	1.74 ± 0.03[c]	2.42 ± 0.12[a]	2.03 ± 0.03[b]	0.0005
PUFA/SFA	1.33 ± 0.05[b]	1.44 ± 0.03[a]	1.20 ± 0.04[c]	0.004	1.34 ± 0.01[a]	1.38 ± 0.02[a]	1.06 ± 0.01[b]	< 0.0001
AI	0.37 ± 0.03	0.34 ± 0.02	0.33 ± 0.01	NS	0.34 ± 0.03	0.35 ± 0.02	0.38 ± 0.01	NS
TI	0.29 ± 0.02[b]	0.3 ± 0.01[b]	0.34 ± 0.01[a]	0.02	0.29 ± 0.01[b]	0.31 ± 0.01[b]	0.37 ± 0.01[a]	0.0004
H/H	3.63 ± 0.22[a]	3.58 ± 0.15[a]	2.81 ± 0.02[b]	0.005	3.65 ± 0.1[a]	3.8 ± 0.05[a]	2.81 ± 0.1[b]	0.0001

[1] Data are expressed as mean ± SD (n = 3). Different letters in the same line indicate significant differences between the analyzed tissues for each sex. *NS* = not significant*; CH* = Cheliped muscles; *CE* = Cephalothorax muscles; *HEP* = Hepatopancreas; *AI* = Atherogenic index*; TI* = Thrombogenic index*; H/H* = Cholesterolemic index.

a decrease in production quantity and quality and an increased frequency of fishing net renewal. Similar impacts of blue crabs were described by Kampouris *et al.* (2019) where the study presented evidence that the invasive crab *C. sapidus* preys on a wide range of species, including economically important fish, mollusks, and crustaceans in the Aegean Sea. In fact, the same scenario has already been observed with *P. segnis* (Khamassi *et al.*, 2019) and also with other invasive decapods, namely the spider crab *L. dubia* H. Milne Edwards, 1834, which caused an alarming shortfall of more than 70% in a single year (Rjiba-Bahri *et al.*, 2019).

To outline an effective management strategy to mitigate ecological and economic impacts of the blue crab in invaded habitats, Mancinelli *et al.* (2017) presented a SWOT analysis for *C. sapidus* invasion. This study concluded that crab explosion control can be coordinated with the opportunity to value it as a fishery resource for alimentary and non-alimentary purposes especially as this species seems to be more delicious (Piras *et al.*, 2019). Commercial fisheries of *C. sapidus* already exist in both native and invaded eastern Mediterranean areas (Turkey) (Piras, 2019). Since the commercial value of crabs depends on their meat yield (Pinheiro *et al.*, 2015), this was evaluated in this study. Sex variations of the meat yield are in agreement with those of Tureli *et al.* (2000) for the same species but also for other crabs such as *Callinectes bocourti* A. Milne-Edwards, 1879 [in A. Milne-Edwards, 1873-1880], *Portunus pelagicus* (Linnaeus, 1758), *Ucides cordatus* (Linnaeus, 1763), and *Cancer pagurus* (Linnaeus, 1758) (Tureli *et al.*, 2000; Yomar Hattori *et al.*, 2006; Barrento *et al.*, 2010; Pinheiro *et al.*, 2015), which usually varies with sex and animal maturity (Pinheiro *et al.*, 2015). During the reproductive period, females use more energy than males for vitellogenesis; thus, they have lower weight and meat yield than males (Barrento *et al.*, 2010; Pinheiro *et al.*, 2015). In addition, there is a sexual dimorphism in most crab species: males have bigger claws than females used in copulation process and intraspecific confrontations (Pinheiro *et al.*, 2015; Rjiba-Bahri *et al.*, 2019). Therefore, large male crabs are always selected by fishermen and requested by retailers and restaurant managers (Maulvault *et al.*, 2012; Pinheiro *et al.*, 2015). Compared to *C. sapidus* caught from Turkish coasts, our analyzed samples had lower flesh contents in both the cephalothorax and chelipeds (total meat yield of Turkish crabs was 57.19% and 66.67%, respectively, for females and males; Yomar Hattori *et al.*, 2006). This could be due to endogenous sources of variations but also meat extraction methods (mechanical vs. manual processes) (Pinheiro *et al.*, 2015). Nevertheless, *C. sapidus* had higher muscle yield than *Portunus pelagicus* (29%–41%; Tureli *et al.*, 2000; Wu *et al.*, 2010) and other high commercial value crabs such as *Cancer pagurus* (total meat yield ranged between 22% and 24%) and *Chionoecetes opilio* (O. Fabricius, 1788) (30%) (Barrento *et al.*, 2010). Also, several studies associated crabmeat yield with body structure and feeding habits (Taylor *et al.*, 2000). Some brachyuran species, which mainly feed on bivalves, contain higher meat content in their chelipeds (Taylor *et al.*, 2000; Yomar Hattori *et al.*, 2006). Moreover, meat yield of the cephalothorax may vary with the morphology and size of thoracomere chambers (small cavities covering the muscle tissue inside the carapace and separated by endophragmal exoskeleton): large thoracomeres with thin and easily breakable septa facilitate meat removal thereby increasing the meat yield (Taylor *et al.*, 2000; Yomar Hattori *et al.*, 2006; Pinheiro *et al.*, 2015). For locomotory pereiopods, flesh content was lower than other body structure in *C. sapidus*, similar to results found for most crabs except the spider crab *Chionoecetes* sp. (muscle contents were similar in claws and locomotory pereiopods) (Yomar Hattori *et al.*, 2006).

The determination of the Atlantic blue crab meat yield could be very useful for crab producers in Tunisia especially as this species had not been investigated prior to this study, unlike the invasive Lessepsian crab *P. segnis* (GIPP, 2019). It is recommended for processing industries that crab abdomen muscles should be sold as vacuum packed or canned crabmeat and the whole claws can be marketed frozen in vacuum packs. In fact, processed crabmeat (frozen or canned) has a higher commercial value and an extended shelf-life than the fresh crabmeat. For the remaining body parts (pereiopods, hepatopancreas, and shells), they can serve as protein and mineral resources in pet food or aquatic feed ingredients but also for chitosan extraction (Yomar Hattori *et al.*, 2006). Therefore, this invasive crab might represent an alternative source for Tunisian fishermen to improve their livelihoods and decrease the recorded negative socio-economic impacts.

Several studies considered only crustacean muscles as edible tissue (Maulvault *et al.*, 2012; Ayas, 2016; Bejaoui *et al.*, 2017). However, the brown meat (hepatopancreas and gonads) is also highly appreciated in Asia, Canada, and southern Europe for its specific aroma and texture (Barrento *et al.*, 2010; Wu *et al.*, 2010) despite the European Food Safety Authority (EFSA) advisories to limit consumption (European Commission, 2011). Even in Tunisia, there are specific culinary habits in southern regions (Sfax and the archipelago of Kerkennah) which have recipes based on cuttlefish hepatopancreas. Therefore, knowing the biochemical analysis and the comparison of the different edible tissues is essential. Results showed significant differences between sexes and tissue samples. Similar variations were found with the same species in Turkish waters and other crabs such as *Cancer pagurus* and *Portunus segnis* (Kücükgülmez *et al.*, 2006; Barrento *et al.*, 2010; Wu *et al.*, 2010; Ayas, 2016; Bejaoui *et al.*, 2017). Comparable moisture contents were found with crabs from Turkish lagoons (65–69%) (Maulvault *et al.*, 2012), whereas higher percentages were reported for the same species in Italian lagoons (Zotti *et al.*, 2016). This relatively high moisture content is essential for crab stabilization during movement. However, strict sanitary measures must be taken during storage and conditioning of crabs, to minimize spoilage.

Similar protein contents in female muscles were reported by (Maulvault *et al.*, 2012) (26.5–29.6%), but lower percentages were noted for the same species in Turkish and Italian waters (14.71%–24.33%) (Tureli *et al.*, 2000; Kücükgülmez & Çelik, 2008; Zotti *et al.*, 2016). In addition, many other species contained lower protein concentrations for both sexes and their tissues (muscles and hepatopancreas), namely *Carcinus aestuarii* (11.514 ± 0.637%), *Scylla serrata* (Forskål, 1775) (11–12%), *Portunus segnis* (2.4–3.0%), and *Portunus pelagicus* (8.4–18.4%) (Wu *et al.*, 2010; Bejaoui *et al.*, 2017). The studied invasive crab has higher protein and lipid contents compared to other decapods of great commercial value, namely *Penaeus kerathurus* (Forskål, 1775), *Penaeus aztecus* Ives, 1891, *Homarus gammarus* (Linnaeus, 1758), *Nephrops norvegicus* (Linnaeus, 1758), *Aristeus antennatus* (Risso, 1816), and *Palinurus elephas* (J.C. Fabricius, 1787) (Rosa & Nunes, 2003; Barrento *et al.,* 2009; Zlatanos *et al.,* 2009; Limam *et al*., 2014; Kampouris *et al.,* 2021). Protein and fat percentages varied from 15.6% to 21.7% and from 0.15% to 2.1%, respectively, of wet weights of these species.

Protein variations can be influenced by species, physiological stage, and environmental conditions (Kücükgülmez & Çelik, 2008; Barrento *et al.*, 2010). Compared to some important commercial fish species (*Sparus aurata*, *Dicentrarchus labrax* (Linnaeus, 1758), wild-caught *Diplodus sargus* L., and *Sciaena umbra* L.) but also other conventional protein sources including poultry (28%), beef meat (26%), fish (15-20%), eggs (12.35%), and milk (8.15%), the invasive blue crab had higher protein concentrations (Ozden & Erken, 2007; Bejaoui *et al.*, 2017; Kouroupakis e*t al.,* 2019).

Regular protein intake is essential for human survival and demand for high quality proteins has increased. To provide this, marine resources are more intensively exploited since they have better digestibility (Kücükgülmez *et al.*, 2006; Bejaoui *et al.*, 2017). Crabs are an excellent protein source especially for children and pregnant and lactating women and may be considered as a "food of the future" in Tunisia. In this context, chelipeds and cephalothorax muscles of *C. sapidus* can provide ca. 50% of the recommended daily protein intake for a person (50–60 g for an individual weighing between 60 and 70 kg (FAO/WHO/UNU, 1985). In fact, Kücükgülmez & Çelik (2008) reported that 50 g of *C. sapidu*s meat can provide the recommended daily essential amino acids requirement for an adult as stipulated by the World Health Organization (WHO) (FAO/WHO/UNU, 1985).

Furthermore, lipid content was the highest in the hepatopancreas and is responsible for the aroma and creamy texture of the brown meat. Several studies have reported similar results for the same species (Kücükgülmez *et al.*, 2006), but also other crabs (*Cancer pagurus* by Barrento *et al.*, 2010), whereas higher lipid content was found in muscles of *Portunus segnis* in Tunisia (9–11%; Bejaoui *et al.*, 2017). Therefore, *C. sapidus* can be recommended like most crustaceans in low fat diets since it provides less than 25% of energy from fat content (Barrento *et al.*, 2010).

Given that muscle is a structural tissue, it contains high protein and poor lipid percentage (Barrento *et al.*, 2010). However, the hepatopancreas is a multifunction organ responsible for the absorption and storage of lipids and cholesterol metabolism (Barrento *et al.*, 2010). Overall, *C. sapidus* represented a similar fatty acid profile to that of other marine crabs (Kücükgülmez & Çelik, 2008; Barrento *et al.*, 2010; Wu *et al.*, 2010; Bejaoui *et al.*, 2017). It was dominated by the PUFA which is in accordance with other studies on blue crabs (Wu *et al.*, 2010; Maulvault *et al.*, 2012; Ayas, 2016; Bejaoui *et al.*, 2017. The highest MUFA content in the hepatopancreatic tissue is a characteristic of the Decapoda (Barrento *et al.*, 2010); this may be related to the importance of MUFA in sexual maturation and larval development (Maulvault *et al.*, 2012). Similar EPA and DHA percentages were reported in muscles of *C. sapidus* sampled in Turkish lagoons (Maulvault *et al.*, 2012; Ayas, 2016). However, lower contents were noted for *Portunus segnis* marketed in Tunisia (2.9–7.6%; Bejaoui *et al.*, 2017). In addition to crab species, the food supply sources strongly affect PUFA composition of marine invertebrates. In fact, aquatic ecosystems are considered as the main source of EPA and DHA production in the biosphere through microalgal species (Bejaoui *et al.*, 2017).

Crabs are known to have a low proportion of SFA and represent a good source of omega 3 PUFA (EPA and DHA) and arachidonic fatty acid (ARA; C20:4 n6). PUFA are considered essential for humans especially fetuses, infants, adolescents, and pregnant or lactating women (Maulvault *et al.*, 2012). They are the major components of cell membrane phospholipids and are predominant in the central nervous system. However, humans are not able to synthesize them, so they must be supplied through the diet (Maulvault *et al.*, 2012). *Callinectes sapidus* muscles represented higher ARA, EPA and DHA concentrations than did the hepatopancreas, since EPA is a structural component of cell membranes in muscles (Wu *et al.*, 2010). These essential fatty acids are known to prevent cardiovascular diseases, some forms of diabetes, and joint inflammation (Bejaoui *et al.*, 2017). Therefore, crab muscles seem to be the healthiest option for human consumption; however, brown crab meat may cause heavy metal poisoning, especially cadmium (European Commission, 2011).

To estimate the nutritional quality of the lipid fraction, some indexes and ratios have been cited as excellent to compare different tissues and species (Ulbricht & Southgate, 1991; UKDH, 1994; Fernandes *et al.*, 2014). The importance of a balanced PUFAs intake has been recognized by health organizations throughout the world and now there is a consensus that the PUFA/SFA and n3/n6 ratios are important. The consumption of foods with higher concentrations of SFA and n6 rather than PUFA and n3 has greater risk of many inflammatory and cardiovascular diseases (Maulvault *et al.*, 2012). The FAO/WHO and the United Kingdom Department of Health recommended a maximum dietary ratio of n6/n3 = 4 (recommended n3/n6 PUFA ratio must be at least between 0.1 and 0.2) and a minimum value of the PUFA/SFA ratio of 0.45 and considers higher ratios more beneficial for human health (UKDH, 1994). In this study, all the analyzed tissues for both sexes showed n3/n6 PUFA and PUFA/SFA ratios that greatly exceeded the recommended minimum values. Compared to the same species sampled from Akyatan lagoon and Hurma strait in Turkey (Maulvault *et al.*, 2012), *C. sapidus* from Tunisian waters is of higher quality regarding n3/n6 PUFA ratios (ranging between 1.29 and 2.24). In addition, abdomen muscles seem to have better nutritional value than the Lessepsian blue crab newly exploited in Tunisia (1.78 and 1.65; 1.13 and 1.23 respectively for n3/n6 and PUFA/SFA ratios values for males and females) (Bejaoui *et al.*, 2017). Furthermore, AI and TI indicate the potential for stimulating platelet aggregation (Ghaeni *et al.*, 2013). The TI tends to form clots in the blood vessels. Additionally, AI reflects the relationship between saturated and unsaturated fatty acids: proatherogenic fatty acids favor the adhesion of lipids to cells of the immunological and circulatory system *versus* anti-atherogenic FA inhibiting the aggregation of plaques, decreasing the levels of cholesterol and phospholipids, therefore preventing the appearance of micro and macro-coronary diseases. Both indexes must be lower than 1 to prevent heart diseases (Ulbricht & Southgate, 1991). In this context, our results show that edible tissues of *C. sapidus*, especially muscles, can be considered as appropriate for human consumption.

Lower AI and TI were found for *Cancer pagurus* (Barrento *et al.*, 2010) and this may be related to species, maturity, sex, season of capture, and nutrient composition of the diet. Nevertheless, higher indices were confirmed for some fishes such *as Sardinella aurita* Valenciennes, 1847 (AI = 0.9 and TI = 0.3), *Merluccius merluccius* (Linnaeus, 1758) (AI = 0.6 and TI = 0.3), *Crangon crangon* (Linnaeus, 1758) (A I=1.35), and *Raja clavata* Linnaeus, 1758 (AI = 2.37) (Ghaeni *et al.*, 2013). In addition, other food items like lamb chops (AI = 1.00 and TI = 1.33), raw minced beef (AI = 0.72 and TI = 1.27), and chicken (AI = 0.5 and TI = 0.95) presented higher indices (Ulbricht & Southgate, 1991).

Finally, there is another essential indicator ratio for evaluating the nutritional value and the healthiness of foods, which is the hypocholesterolemic and hypercholesterolemic fatty acid ratio (H/H) (Fernandes *et al.*, 2014). This additional index considers the specific effects of fatty acids on cholesterol metabolism, thus greater H/H values are more beneficial for human health (Fernandes *et al.*, 2014). The obtained cholesterolemic indexes (H/H) in blue crab were higher than those found in other common food sources namely chicken, rabbit, and beef (respectively 1.8, 1.2, and 1.8; Dal Bosco *et al.*, 2001; Attia *et al.*, 2017). The investigated crab meat was better for retarding atherosclerosis than rabbit meat, well known as low fat food source. All the calculated nutritional indexes of fatty acids profile, namely PUFA/SFA, n3/n6, AI, TI as well as H/H ratios, indicates that the edible tissues of the invasive crab *C. sapidus* are beneficial for human health. As most of biological invasions occur due to anthropogenic vectors and may negatively influence the invaded ecosystems, they are considered as biological pollution (Katsanevakis *et al.*, 2020). Different approaches have been used to control NIS, and their consumption has been applied previously but has recently surged in popularity among governmental and scientific communities (Nuñez *et al.*, 2012; Leone, 2020). The exponential growth rate of the world population will lead to food shortages and resource scarcity. Hence, the challenge is to explore new marine food resources, e.g., invasive species. Eating AIS is also a possible way to improve the economic situation of local fishing sectors (Mancinelli *et al*., 2017; Lavajoo *et al.,* 2018; Castro-González *et al.,* 2019).

For this, food preferences and culinary traditions are changing with better acceptability of new foods like crabs whose consumption was initially limited in Tunisia to only the archipelago of Kerkennah. Note that the Tunisian consumer is currently turning more and more towards fishery products of exotic origins. This change in eating behavior is stimulated by several tasting events organized at a local scale, as part of the national strategy for the control and promotion of exotic marine species. At a regional level, promoting campaigns of NIS consumption, namely "Eat Those Invasives", "Eat Lionfish" were carried out (Nuñez *et al.*, 2012). In addition, online and printed cookbooks supporting the use of NIS as meal components, were published by Franke (2007) and Leone (2020). This can be beneficial for all participants (scientists, government, and fishermen) since it increases awareness of NIS, assists in early detection, and may boost local economy (Nuñez *et al.*, 2012).

Several studies have highlighted the high nutritive value of Mediterranean blue crab meat; however blue crab exploitation initiatives are extremely limited. Tunisia, the main hotspot for *P. segnis and C. sapidus* in the Mediterranean, was the first country to be concerned by this biological explosion and has implemented a national plan for promoting fishing and marketing of the blue swimming crab. Therefore, several tasting campaigns and cooking shows were organized in Tunisia during various national and international events to promote this new product and encourage its consumption. These initiatives were at the origin of new commercial dynamics and new jobs, and mitigated blue swimming crab damage. Therefore, biological explosion turned from being a threat to an opportunity. Tunisian initiatives to manage this bioinvasion can be considered as a case study to be followed at a Mediterranean scale. However, crab stock assessment is required for the sustainability of this new fishery and the implementation of an appropriate value chain.

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