EXAMINATION OF THE NUTRITIONAL VALUE OF FOUR BIVALVES SPECIES FROM BIZERTE LAGOON

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ملخص

دراسة القيمة الغذائية لأربعة أنواع من ذوات الصدفتين من بحيرة بنزرت : تعتبر ذوات الصدفتين اختيارًا غذائيًا صحيًا بسبب محتواه العالي من العناصر الغذائية بما في ذلك الأحماض الدهنية ، والأحماض الدهنية المتعددة غير المشبعة بشكل أساسي.الغرض من هذه الدراسة هو تقديم معلومات عن الصفات الغذائية لأربعة أنواع من ذوات الصدفتين ذات القيمة العالية التي تم حصادها من بحيرة بنزرت في الربيع.كما تم تحديد مؤشرات النسبة المئوية الصلاحية للأكل ، مؤشر الحالة ، البروتين ، الدهون ، الرطوبة ، الجليكوجين ، الأحماض الدهنية ومؤشرات الجودة الغذائية.وفقا لنتائجنا، قد لوحظت نسب عالية لصلاحية الأكل و مؤشر الحالة في جميع ذوات الصدفتين.أظهرت النتائج التي توصلنا إليها أن جميع ذوات الصدفتين يمكن اعتبارها أغذية صحية بسبب محتواها العالي من البروتين والدهون والأحماض الدهنية الغير المشبعة وجودتها الغذائية.

إن المستويات العالية من التركيب الكيميائي الحيوي والأحماض الدهنية التي لوحظت في هذه الدراسة تجعل أكثر ملائمة لصحة المستهلكين *L. lithophaga* و *M. galloprovincialis*

سيكون هذا العمل مفيدًا للمستهلكين وأداة تسويقية رائعة لمزارعي المحار.

الكلمات المفتاحية: ذوات الصدفتين ، التركيبة البيوشمية ، الأحماض الدهنية ، القيمة الغذائية.

ABSTRACT

Bivalves are known as a healthy nutrition choice due to the highest amounts of nutrients comprising fatty acids mainly polyunsaturated fatty acids (PUFAs). The study is conducted to provide information about the nutritional qualities of four bivalves species (*Mytilus galloprovincialis, Cerastoderma edulis, Venus verrucosa and Lithophaga lithophaga*) of great commercial value collected from Bizerte lagoon during spring season. The edibility percent, condition index, protein, lipid, moisture, glycogen, fatty acids and nutritional values indices have been also determined. According to our results, high edibility percent and condition index were observed in all investigated bivalves. The results showed that all bivalves could be considered dietary food due to their important contents of proteins, lipid, essential polyunsaturated fatty acids (PUFA), and nutritional quality. The significant contents of the biochemical and fatty acid compositions observed in the present study make *L. lithophaga* and *M. galloprovincialis* more appropriate for consumers' health. This work will be useful for consumers and an impressive marketing tool for shellfishing farmers.

Keywords: Bivalves, proximate composition, fatty acids, nutritional value.

RESUME

Examen de la valeur nutritionnelle de quatre espèces de bivalves de la lagune de Bizerte : Les bivalves constituent un choix nutritionnel sain en raison de leur teneur élevée en nutriments comprenant des acides gras, principalement les acides gras polyinsaturés (AGPI). Cette étude visait à fournir des informations sur les qualités nutritionnelles de quatre espèces de bivalves (*Mytilus galloprovincialis, Cerastoderma edulis, Venus verrucosa et Lithophaga lithophaga*) de grande valeur commerciale, récoltées de la lagune de Bizerte au printemps. Les indices de pourcentage de comestibilité, l'indice de condition, les tenerus en protéines, lipides, humidité, glycogène, acides gras et les indices de la qualité nutritionnel ont également été déterminés. Selon nos résultats, les pourcentages de comestibilité et d'indice de condition élevés ont été observés chez tous les bivalves étudiés. Nos résultats ont montré que tous les bivalves pouvaient être considérés comme des aliments diététiques en raison de leur teneur élevée en protéines, en lipides, en acides gras polyinsaturés (AGPI) et en qualité nutritionnelle. Les teneurs importantes de la composition biochimique et des acides gras observées dans la présente étude rendent *L. lithophaga* et *M. galloprovincialis* plus appropriés pour la santé des consommateurs. Ce travail sera utile pour les consommateurs et un outil de marketing impressionnant pour les éleveurs de coquillages.

Mots clés: Bivalves, composition biochimique, acides gras, valeur nutritionnelle.

INTRODUCTION

Lagoons are closest coastal areas extremely productive and considered as the main ecologic and socio-economic systems that produce important resources for consumers.

Among these systems, Bizerte lagoon is a transitional area characterized by extreme daily variations of environmental parameters set. Since the 20th century, Bizerte lagoon is considered as the most produced ecosystems in term of shellfishing of various bivalve species such as oyster (*Ostrea edulis, Crassostrea gigas*) and mussel *(Mytilus galloprovincialis*).

During the last years, the production of bivalves has been increased considerably in relation to consumer demand (Prato et al., 2019). In the Mediterranean countries, mainly Tunisia, bivalves are considered as a rich food source and a healthy proportionate diet (Dridi et al., 2007; Ghribi et al., 2018; Cherifi et al., 2018). Since, they are generally known by their nutritive rate which is described by an essential quantity of protein, vitamins, and polyunsaturated fatty acids (PUFA) principally docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA). Generally, the habitual consumption of bivalves is suitably related to the prevention of many diseases such as cardiovascular, inflammatory and cancers (Shaikh et al., 2014). Additionally, current reports have established that the nutritional value of many bivalves' species is linked to their anti-arrhythmic, anti-thrombotic and anti-inflammatory properties (Pao-Yen *et al.*, 2012).

The purpose of the present investigation was to describe and evaluate the edibility percent, condition index, biochemical composition (proximate and fatty acids) and the nutritional value of four important bivalves (*Mytilus galloprovincialis, Cerastoderma edule, Venus verrucosa* and *Lithophaga lithophaga*) collected from Bizerte lagoon.

MATERIALS AND METHODS

Sampling bivalves and tissues preparation

Bivalves' species (*Mytilus galloprovincialis, Cerastoderma edulis, Venus verrucosa and Lithophaga lithophaga*) were collected from Bizerte lagoon by scuba divers during February 2017. Bivalves were immediately transferred to the laboratory in cool tanks. In the laboratory, shell length (L), width (W) and total weight (TW) were measured (Table I), then, soft tissues were removed. Some portions were homogenized with Tris-HCL buffer (ph 7.4), centrifuged during 20min at 7000×g and storage at -80°C until biochemical analysis. Other portions were conserved at -80°C for fatty acid analysis. The storage period was not longer than 10 days.

Table I: Biometric index of four commercial bivalves' species on a wet weight basis collected from Bizerte lagoon.

	SL (mm)	**Sw (mm)**	**TW (g)**
M. galloprovincialis	62.7± 5.1	35.1± 3.8	11.6± 0.8
C. edulis	21.6± 1.8	26.5± 1.0	5.3 ± 0.1
V. verrucosa	43.5± 1.2	49.4± 3.9	7.4 ± 0.7
L. lithophaga	80.2± 2.4	25.6± 0.9	12.0± 2.3

Biometrical analysis

Edibility percent (EP) and condition index (CI) were determined according to Mohite et al (2008) and Okumus and Stirling (1998) respectively as follows:

EP= (wet weight/total weight) × 100

CI= (wet weight/ shell weight) × 100

Biochemical composition analysis

Moisture (%) was evaluated according to AOAC (2005) by weight change after drying the tissues at 105±3°C for 24 h. Glycogen content was determined basing on Dubois et al. (1956) method. Protein content was assessed as reported by Lowry et al. (1951) using bovine serum albumin (BSA) as standard. Total lipids contents were determined according to the method of Frings et al (1972). Briefly, 20µl of each sample was treated with 200 ml of concentrated H_2SO_4 and heated in boiling water for 10 min. After cooling, 10 ml of phosphor-vanillin reagent was added. The mixture was incubated at 37^o C for 15 min; the samples were then read at 540 nm. A good U.S. grade of olive oil (Sigma, St. Louis, USA) was used as a standard. The total lipids content was calculated by reference to a standard curve. Results of proteins, glycogens and total lipids were expressed as mg/g of weight wet.

Fatty acid analysis

Lipids were extracted according to the method of Folch et al. (1957) using the mixture solution of chloroform-methanol (2:1, v/v) containing butylated hydroxyl toluene (0.01%) as an antioxidant. According to Cecchi et al. (1985), fatty acids (FA) were trans-methylated from the extract lipids and

nonadecanoic acid (C19:0 Belefonte PA, USA, CRM47885) was added as an internal standard. The obtaining fatty acid methyl esters (FAMEs) were analyzed through gas chromatography (HP, 6890 GC) using nitrogen as a carrier gas. The GC was equipped with an injector with a flame ionization detector, and a 30m HP Innowax capillary column characterized with an internal diameter of 250mm and a film thickness of 0.25mm. The injector and detector temperatures were maintained at 250°C and 275°C, respectively. The oven temperature was automatically programmed to increase from 50 to 180°C at a quickness of 4 °C/min, from 180°C to 220°C at 1.33°C/min and then stabilized at 220°C for 7 min. FAMEs were integrated (HP chemstation software) and identified based on the commercial standards methyl esters (SUPELCO polyunsaturated fatty acids (PUFA-3)). FA content was expressed as mg/g of the total amount of FA.

Nutritional quality indices (Table II)

Table II: The nutritional values of the studied bivalves were evaluated using several indices as follows:

	Index	References
1	n-3/n-6 PUFA	Marques *et al.*, 2010
2	EPA+DHA	Marques *et al.*, 2010
3	AI=((12:0+ (4×14:0) +16:0)) / (ΣMUFAs+PUFAn6+PUFAn3)	Ulbricht and Southgate (1991)
4	TI=(C16:0+C18:0) / (0.50*MUFA) + (0.5*PUFA n-6) + (3* PUFA n-3) + (PUFA n-3 /PUFA n-6)	Ulbricht and Southgate (1991)

Statistical analysis

Data were presented as means ± standard deviations (SD) of 15 replications for moisture, proteins, glycogens, and lipids, while 6 samples were used for FA content. The homogeneity and normality of our results were analyzed through the software STATISTICA 8 (Stat-Soft Inc.) using the Shapiro-test. The significant differences between variables were detected at 5% and tested with one way (ANOVA) followed by a post-hoc Tukey's test and with Kruskall–Wallis's test. Principal components analysis (PCA) was also determined to display the most richness species in term of biochemical, FA and nutritional value.

RESULTS

Biometrical measurement of the studied bivalves

The results of the biometric indices of *M. galloprovincialis*, *V. verrucosa*, *C. edule* and *L. lithophaga* are presented in Table III. EP varied significantly among studied species (p<0.01), ranging from 37.9 to 75%. The maximum percent was recorded in *L. lithophaga* tissues, while the lowest one was observed in *C. edule*. However, CI did not varied significantly between the studied species (p>0.05).

Table III: Edibility percent (EP) and condition index (CI) of four commercial bivalves' species collected from Bizerte lagoon.

		EP (%)	CI (%)
M. galloprovincialis		68.7±3.7	67.5±5.3
C. edulis		37.9±4.1	81.4±4.1
V. verrucosa		54.0±1.5	77.3±6.1
L. lithophaga		75.3±2.2	79.6±8.3
	F	23.69	31.89
	P	**	ND

Values are presented as means ± standard deviations.
Significant difference was detected at 5%: **<0.01.
Edibility percent of (PE) and condition index (CI),
No difference (ND).

Proximate composition of the studied bivalves

Proximate compositions of the studied bivalves were presented in Table IV.

Table IV: Proximate composition of the four commercial bivalves' species collected from Bizerte lagoon.

		Moisture α	Glycogen β	Protein β	Lipid β
M. galloprovincialis		79..3± 6.0	6.6± 0.5	5.6± 0.1	22.6± 1.1
C. edulis		75.7± 2.8	2.6± 0.8	3.7± 0.6	12.6± 0.9
V. verrucosa		80.5± 3.3	4.9± 0.4	6.1± 0.0	20.4± 3.5
L. lithophaga		81.4± 1.8	11.2± 1.4	7.5± 0.7	25.1± 2.9
	F	23.56	1.059	6.98	17.66
	P	**	***	**	***

Values are presented as means ± standard deviations.
Significant difference was detected at 5%: **<0.01 and ***<0.001. α : percent; β :mg/g of ww.

The most abundant compound in the edible flesh was the moisture. Our results showed a significant difference between the studied bivalves, with a maximum percent founded in *L. lithophaga* (81%), *V. verrucosa* (80%) and *M. galloprovincialis* (79%). However, *C. edule* specimens were characterized

with a lower percent of moisture (75%). The glycogen content was found to be higher in *L. lithophaga* (11.2 mg/g) and lower in *C. edule* (2.6 mg/g) (p<0.001). In this present study bivalves showed significant differences in protein content, that ranged from 3.7 to 7.5 mg/g between the studied species. The highest content was recorded in *L. lithophaga* (7.5 mg/g) followed by *V. verrucosa* (6.1 mg/g) and *M. galloprovincialis* (5.6 mg/g). Although, *C. edule* was characterized by the lowest content (3.7 mg/g). The lipid content varied significantly between all the examined species (p<0.001). *L. lithophaga* and *M. galloprovincialis* exhibited the highest contents (25.1 and 22.6 mg/g respectively) followed by *V. verrucosa* (20.4 g/mg). While, specimens of *C. edule* showed a lowest content of lipids than the other studied species (12.6 g/mg).

Fatty acid composition of the studied bivalves

Fatty acid profiles of the four studied bivalves were reported in Table V. FA of the examined species were dominated by polyunsaturated fatty acid (PUFA) followed by saturated fatty acid (SFA) and monounsaturated fatty acid (MUFA). *C. edule*, was an exception, with approximately comparable amounts of PUFA and SFA.

Table V: Fatty acid composition (mg/g) of four commercial bivalves' species collected from Bizerte lagoon

	M.galloprovincialis	***C. edulis***	***V. verrucosa***	***L. lithophaga***	***P***
C14:0	1.37 ± 0.34	1.06± 0.15	1.09± 0.02	1.11 ± 0.03	ND
C15:0	1.44 ± 0.05	1.19 ± 0.02	1.54 ± 0.41	1.92 ± 0.17	ND
C16:0	8.95 ± 1.17	9.33 ± 1.14	9.45 ± 0.15	9.31 ± 0.85	ND
C18:0	10.10 ± 0.95	15.99 ± 0.43	8.91 ± 0.04	9.24 ± 0.15	*
SFA	**20.87 ± 4.68**	**28.59± 2.10**	**22.28± 0.79**	**21.60 ± 0.98**	*
C15:1	1.00 ± 0.95	1.12 ± 0.05	1.36 ± 0.44	1.30 ± 0.55	ND
C16:1	7.30 ± 0.90	6.93 ± 0.40	6.77 ± 4.59	7.21 ± 0.42	ND
C18:1	9.49 ± 0.75	8.27 ± 0.61	8.83± 1.58	9.03± 2.56	ND
MUFA	**17.79 ± 5.72**	**16.66 ± 0.57**	**16.96 ± 3.66**	**17.54± 3.78**	ND
C16:2	1.38 ± 0.18	1.62 ± 0.08	2.70 ± 0.92	3.38 ± 0.85	*
C16:3	1.41 ± 0.06	1.18 ± 0.02	1.61 ± 0.38	2.01 ± 0.48	ND
C16:4	0.72 ± 0.08	0.32 ± 0.02	1.25 ± 0.32	1.56 ± 0.27	***
C18:2n-6	5.30 ± 0.98	2.38 ± 0.44	3.05 ± 0.33	4.82 ± 0.78	**
C18:3n-6	1.69 ± 0.46	0.76 ± 0.04	2.81 ± 0.65	1.76 ± 0.57	**
C18:3n-3	4.88 ± 0.58	2.19 ± 0.2**6**	1.46 ± 0.2**1**	2.57 ± 0.07	***
C18:4n-3	1.52 ± 0.67	0.68 ± 0.02	1.06 ± 0.11	1.33 ± 0.21	ND
C20:2n-6	2.36 ± 0.05	2.16 ± 0.02	3.40 ± 0.51	3.25 ± 0.63	*
C20:3n-6	0.62 ± 0.13	0.27 ± 0.05	3.42 ± 0.36	1.52 ± 0.82	***
C20:4n-6	1.31 ± 0.42	0.59 ± 0.12	0.43 ± 0.09	0.54 ± 0.09	*
C20:3n-3	0.95 ± 0.01	0.43 ± 0.04	0.44 ± 0.06	1.05 ± 0.23	**
C20:5n-3	5.79 ± 0.60	2.60 ± 0.72	4.33 ± 0.26	7.91 ± 0.64	***
C22 :2i/2j	4.80 ± 0.95	5.31 ± 0.41	3.25 ± 0.13	4.06 ± 0.16	*
C22:5n-6	3.85 ± 0.45	1.73 ± 0.18	2.52 ± 0.51	3.16 ± 0.70	*
C22:5n-3	1.51 ± 0.84	0.68 ± 0.03	3.24 ± 0.21	1.55 ± 0.46	***
C22:6n-3	8.26 ± 0.37	4.16 ± 0.17	6.85 ± 0.00	11.06 ± 0.38	***
PUFA	**46.37 ± 4.32**	**27.6± 1.94**	**43.85± 2.78**	**54.53± 3.87**	***
PUFA n-3	**22.91 ± 2.84**	**10.74± 1.28**	**18.40± 3.19**	**25.46± 3.99**	***
PUFA n-6	**15.15 ± 1.35**	**7.89 ± 0.60**	**15.04± 3.27**	**15.50± 4.07**	***

Values are presented as means ± standard deviations. Significant difference was detected at 5%: *<0.05, **<0.01 and ***<0.001. SFA saturated fatty acid, MUFA: monounsaturated fatty acid (MUFA), PUFA: polyunsaturated fatty acid (PUFA), ND: no difference

The PUFA ranged from 27.90 mg/g to 48.85 mg/g in the edible tissues of *C. edule* and *L. lithophaga* respectively. The mainly PUFA groups were n-3 PUFA and n-6 PUFA which showing significant differences between the examined bivalves (p<0.001). The n-3 PUFA group was dominated in the edible tissues of *L. lithophaga* (25.46 g/mg) and *M. galloprovincialis* (22.91 g/mg), characterized by an important amount of docosahexaenoic (DHA) (11.06 and 8.26 mg/g, respectively) and ecosapentaenoic (EPA) (7.91 and 5.79 mg/g, respectively). Also, n-6 PUFA contents were lower than n-3 PUFA, showing a statistical difference between the studied species (p<0.001), ranged from 7.89 mg/g in the edible tissues of *C. edule* to 15.50 mg/g in *L. lithophaga*. This group was dominated by

linoleic (C18:2n-6), linolenic (C18:3n-6), ecosanoic (C20:2n-6), ecosatrienoic (C20:3n-6) and arachidonic (C20:4n-6) acids that exhibited significant differences among studied species (p<0.05).

Likewise, significant variation was recorded for SFA and stearic (C18:0) acids, showing a maximum content in the dibble tissues of *C. edule* (28.59 and 15.99 mg/g respectively) than *M. galloprovincialis* (20.87 and 10.10 mg/g respectively), *V. verrucosa* (22.28 and 8.91 mg/g respectively) and *L. lithophaga* (21.60 and 9.24 mg/g respectively) (p<0.05).

However, MUFA content varied similarly in the edible tissues of the studied species with no significant difference (p>0.05).

Values are presented as means ± standard deviations. Significant difference was detected at 5%: *<0.05, **<0.01 and ***<0.001. SFA: saturated fatty acid, MUFA: monounsaturated fatty acid (MUFA), PUFA: polyunsaturated fatty acid (PUFA), ND: no difference.

Nutritional value of the studied bivalves

The nutritional values of the examined bivalves are presented in Table VI. Our results showed that *L. lithophaga* exhibited significant amount of n-3/n-6 PUFA (1.64) and EPA+DHA (18.97) than the other studied bivalves. However, the lowest quality was recorded in the edible tissues of *C. edule* (p<0.05). Conversely, AI and TI were higher in the edible tissues of *C. edule* followed by *V. verrucosa*, *M. galloprovincialis* and *L. lithophaga*, showing significant differences between them (p<0.01).

Table VI: Nutritional quality indexes of four commercial bivalves' species collected from Bizerte lagoon

	n-3/n-6	EPA+DHA	AI	TI
M. galloprovincialis	1.51± 0.05	14.05±1.23	0.21± 0.03	0.21±0.07
C. edulis	1.36± 0.77	6.76 ± 0.12	0.38± 0.11	0.48±0.03
V. verrucosa	1.10± 0.04	11.18± 2.6	0.27±0.03	0.25±0.01
L. lithophaga	1.64± 0.31	18.97±1.78	0.23±0.04	0.19±0.03
F	9.41	16.92	5.802	20.751
P	*	***	**	***

Values are presented as means ± standard deviations. Significant difference was detected at 5%: *<0.05, **<0.01 and ***<0.001.

Principal component analysis (PCA)

In this study, the PCA accounted more than 89.26% of the total variation (Fig. 1). The first two factors (PC1 and PC2) explained 73.88% and 15.38% of the variation respectively. Results confirmed a clear separation between the examined bivalves. In fact, *M. galloprovincialis* and *L. lithophaga* have an important quality followed by *V. verrucosa*. These bivalves were correlated with the highest values of moisture, proteins, lipids, PUFA, DHA, EPA, n-3 PUFA, n-3/n-6 and EPA+DHA. However, *C. edule* was characterized with the lowest nutritional value, correlating with the highest contents of SFA, AI and TI.

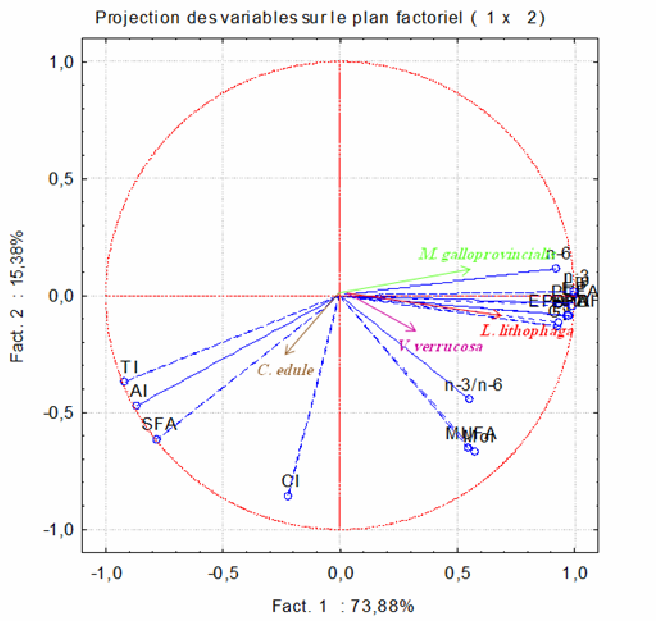

Figure 1: Principal component analysis including the examined bivalves (*M. galloprovincialis, V. verrucosa, C. edule and L. lithophaga*) and the tested parameters.

DISCUSSION

In Tunisia, the production of shellfish has been significantly increased. Due to the lake of information about the nutritional value of the most edible bivalves, it is important to provide useful and applicable information about their benefit proprieties for the consumers. Our study delivered for the first time new information about the marketability values of four bivalves species collected from Bizerte lagoon.

Several studies have demonstrated that the EP and CI are the main tools for the commercialization of bivalves, depending generally to the endogenous and exogenous conditions (Gabbott, 1975; Lagade et al., 2015). In this regards, all studied species in the present work were collected during the ripe gonads. According to our results, the EP varied greatly between the tested bivalves revealing the best quality of bivalves flesh. Withal, CI showed a similar variation among the examined bivalves. Analogues results were reported on bivalves' species from Bizerte lagoon (Ghribi et al., 2018), Mediterranean Sea (Prato et al., 2019), and Atlantic Sea (Anibal et al., 2011).

Previous investigations have reported that the biochemical components such as lipids, proteins and carbohydrates changed among bivalves and related to the environmental factors and the gametogenic process (Orban et al., 2002). Generally, the proximate composition of flesh considered as an essential tool for resolving it nutritive value and it marketable qualifications. In the literature, little information is published on the nutritional value and biochemical composition of the most studied bivalves. Moreover, these reported results on the biochemical composition for the same bivalves are often information about other region and ecosystems.

The flesh of the examined species was characterized by high amount of moisture followed by lipid glycogen and protein contents. This considerable percent of moisture could revealed the flesh value, since, it is widely reported to reflect the freshness of several bivalves species such as Verinids, Oyster, Mytilids, …etc (Ojea et al., 2004; Dridi et al. 2007; Ovissipour et al. 2013).

Lipids are reported as energy storage and play an important role in the metabolic pathways and functions of bivalves' species (Sztalryd and Kimmel, 2014). The most important content was observed in the edible flesh of *L. lithophaga*, *M. galloprovincialis* and *V. verrucosa* while *C. edule* was characterized by the lowest content. Our results were in agreement with the studies of Orban et al (2006) and Berik et al. (2017) carried out on *Chamelea gallina* and *Flexopecten glaber* respectively. Nevertheless, our results were higher than other investigations in the literature reported on bivalves from Spanish coast Black Sea and Mediterranean Sea (Fuentes et al. 2009; Dernekbasi et al. 2015).

The amount of protein and glycogen is extremely important when considering the quality and the texture of seafood (Løje et al., 2007). Among the studied bivalves, *L. lithophaga* has the most richness flesh in term of protein and glycogen followed by *M. galloprovincialis* and *V. verrucosa*. Protein and glycogen contents in the studied bivalves were similar to that found in *M. galloprovincialis* from Adriatic Sea and Spanish coast and (Bongiorno et al. 2015; Azpeitia et al., 2016). Other researchers have reported similar results for bivalves from Italian coast and Mediterranean Sea (Ghribi et al., 2018; Prato et al., 2019).

Fatty acids are important component that used by the organisms for various metabolic and structural function. It is well reported that the high amount of PUFA was feature of a healthy bivalves flesh (Dupčić et al., 2014). In our study, the fatty acid profile of *L. lithophaga*, *M. galloprovincialis* and *V. verrucosa* showed dominance of PUFA over SFA and MUFA as compared to *C.edule* which characterized with similar PUFA and SFA contents. Our data are in harmonies with previous reports carried on *M. galloprovincialis* (Irisarri et al., 2014; Cherifi et al., 2018) and Arca noea (Ghribi et al., 2018). Prato et al (2019) have reported similar amount of PUFA and SFA in the edible flesh of *Mimachlamys varia* from southern Italy as the obtained *C. edule* profile in our study. In line with this, it is well reported that the high consumption of SFA could induce the development of coronary heart disease (Kris-Etherton et al., 2002), for this reason, many dietary recommendations advice consumer to reduce the rich food of SFA in order to prevent chronic diseases (Simopoulos, 2008).

Among PUFA, n-3 PUFA was the dominant family in all bivalves, characterized with an important amount of DHA and EPA, confirming the good dietary source of bivalves flesh. Since n-3PUFA have valuable proprieties beside several diseases (obesity, diabetes, cardiovascular and cancers diseases) (Akoh et al., 2017).

Regarding MUFA, it has been considered as good fats, especially when replacing saturated fats in the diet. Quantitatively, MUFA varied similarly in the edible flesh of all studied bivalves. These results corroborate the data described in previous researches (Azpeitia et al., 2016; Ghribi et al., 2018, Prato et al., 2019). Recently, Mashek (2015) have demonstrated that the consumption of MUFA reduce the possibility of cardiovascular diseases.

The most important content of FA was observed for C16:0, C18:0, C16:1, C18:1, C18:2n-6, C20:2n-6, C20:5n-3 (EPA) and C22:6n-3 (DHA), which corroborate with previous reports of Dridi et al (2007), Telahigue et al (2013), Ghribi et al (2018)

and Bejaoui et al (2019) carried out on bivalves species collected from Bizerte lagoon.

The nutritional values of the studied bivalves were evaluated through several indices such as n-3/n-6 PUFA, EPA+DHA, AI and TI that are commonly established to estimate the dietary quality of FA (Neff et al., 2014). Our results show that the greatest contents of n-3/n-6 ratio and EPA+DHA were detected in *L. lithophaga* and *M. galloprovincialis*. Nevertheless, it decreased significantly in *C. edule* and *V. verrucosa*. In line with our results, previous investigations have demonstrated the benefic effects of n-3/n-6 and EPA+DHA to prevent several diseases (cardiovascular, cancers…etc.) (Kim et al. 2007).

The nutritional value of bivalves was also defined through AI and TI indices. These indices are known to reduce the potential risk of many diseases (Ulbricht and Southgate 1991). Our obtained results shown values lower to the previously published data (Joy and Chakraborty 2016; Ghribi et al., 2018) and in the range of the recommended standards in all examined bivalves (HMSO, 1994). These results showed the good nutritional quality of *L. lithophaga* and *M. galloprovincialis* tissues as compared to *V. verrucosa* and *C. edule.*

Taken all these results together, *L. lithophaga* and *M. galloprovincialis* were considered as the most richness bivalves since they have an important correlation with the essential biochemical parameters (protein, lipid, glycogen) and fatty acid compositions such PUFA, n-3 PUFA, EPA and DHA. Currently, few data were founded in the literature of some of the studied bivalves, so that our present investigation promotes additional research.

CONCLUSION

This study could present information to consumers, farmers, food scientist, and nutritionists to promote the culture of these bivalves. One of the objectives of this study was simply to obtain information on the fatty acid profile of these bivalves which are widely appreciated in the markets and have a significant commercial interest. These edible bivalves, from the Bizerte lagoon may be considered as benefic seafood that contributing with important nutritional qualities due to their high contents of protein, lipids, and glycogens and to their contents of fatty acid composition especially DHA, EPA and n-3PUFA. Even the differences among the examined bivalves, there consumption could be beneficial to human health since they have good nutritional values.

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