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Monthly variations of protein and amino acid composition of the smooth scallop *Flexopecten glaber* (Linnaeus 1758) in the Çardak Lagoon (Lapseki-Çanakkale)

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Abstract: In the present study, the total protein and amino acid composition of smooth scallop *(Flexopecten glaber)* meat sampled every month for one year was determined in the Çardak Lagoon (Turkey). The lowest protein level in smooth scallop meat (57.41% dry weight, dw) was found in December, whereas the highest protein level was observed in April (67.62% dw). Essential amino acid concentrations ranged from 16.60 to 20.82 g.100 g^{-1} dw, while non-essential amino acid concentrations ranged from 36.03 to 46.68 g.100 g^{-1} dw. Among essential amino acids, phenylalanine was dominant. The highest essential amino acid contents were observed in winter and spring, while the highest non-essential amino acid contents were observed in summer and autumn. The differences in monthly essential amino acids and non-essential amino acid values were statistically significant ($p < 0.05$).

Résumé: *Variations mensuelles de la composition en protéines et acides aminés chez le pétoncle glabre* Flexopecten glaber *(Linnaeus, 1758) dans la lagune Çardak (Lapseki-Çanakkale).* Dans la présente étude, la composition totale en protéines et en acides aminés du pétoncle glabre (*Flexopecten glaber*) échantillonné chaque mois pendant un an a été déterminée dans la lagune de Çardak (Turquie). Le niveau de protéines le plus bas dans la chair du pétoncle glabre (57,41% poids sec, ps) a été trouvé en décembre, alors que le niveau de protéines le plus élevé a été observé en avril (67,62% ps). Les concentrations d'acides aminés essentiels variaient de 16,60 à 20,82 g.100 g^{-1} poids sec, tandis que les concentrations d'acides aminés non essentiels variaient de 36,03 à 46,68 g.100 g^{-1} poids sec. Parmi les acides aminés essentiels, la phénylalanine était dominante. Les teneurs en acides aminés essentiels les plus élevées ont été observées en hiver et au printemps, tandis que les teneurs en acides aminés non essentiels les plus élevées ont été observées en été et en automne. Les différences dans les valeurs mensuelles d'acides aminés essentiels et d'acides aminés non essentiels étaient statistiquement significatives ($p < 0{,}05$).

Keywords: Flexopecten glaber • Smooth scallop • Amino acid • Histidine • Phenylalanine • Çanakkale Strait

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Introduction

The smooth scallop *Flexopecten glaber* (Linnaeus, 1758), a bivalve belonging to the family Pectinidae, is distributed throughout the Eastern Atlantic, the Mediterranean Sea, and the Black Sea, including the area from Portugal to Morocco. In Turkey, it is observed in intense stocks throughout the Mediterranean from the south of Marmara along with the Aegean sea (Aquamaps, 2019). This species is mostly found on muddy, sandy substrates with shell remains appearing from 5-900 m from the shore (Bondarev, 2018). The depth at which *F. glaber* lives varies from a few meters in sheltered areas to over 200 meters in open seas (Hardy, 2006).

Bivalves are important marine organisms regarded for their nutritional value, flavour and price (Orban et al., 2007). They have a rich nutritional composition, including high protein content, essential amino acids (EAA) and a low-fat content (Orban et al., 2007; Prato et al., 2019a). They contain all of the amino acids involved in the prevention of liver disease, kidney failure, stress and severe burns, as well as the regulation of fat metabolism, growth and repair in the human body (Koral & Süleyman, 2017). Amino acids, such as aspartic acid, glycine and glutamic acid, play a key role in the healing of wounds (Erkan et al., 2010).

In the present study, the protein and amino acid composition of the smooth scallop (*F. glaber*), one of the most economically important bivalve species collected from the Dardanelles Strait in the Turkish Straits System, was determined. The literature contains studies on the mineral, fatty acid and amino acid compositions of smooth scallop meat (Telahigue et al., 2013; Prato et al., 2019a & b), but there are limited studies on the monthly changes in the amino acid composition (Prato et al., 2019a; Pleadin et al., 2019). Therefore, this study aimed to examine the monthly changes in protein and amino acid composition in this species.

Materials and methods

Sample collection

Smooth scallops were collected monthly between July 2017 and June 2018 from the Çardak Lagoon located in Çanakkale Province in Lapseki district (40°22’56"N-21°42’58"E) in Turkey (Fig. 1). The Çardak Lagoon includes the Buruniçi Lagoon, Ortagöl and Burunucu Lagoons, located in the Lapseki district of Çanakkale. The lagoon is under the influence of the sea due to its deep and constantly open passage. The Çardak Lagoon is a 180 ha saltwater lagoon with an average depth of 1.5 m (GTHB, 1997). During the study, 30 smooth scallops were brought to the laboratory every month. Fouling organisms adhering to the smooth scallops were removed using a knife, and was freeze dried after separating the meat from the shell parts. The freeze-dried meat was used to determine the protein and amino acid compositions (percent of dry weight). Because in some studies protein and amino acid contents were determined as compared to wet weight, we also converted results in percent wet weight. A coefficient was used in the conversion to wet meat. In the calculation of this coefficient, the method of El-Shenawy et al. (2016) was used (Table 1).

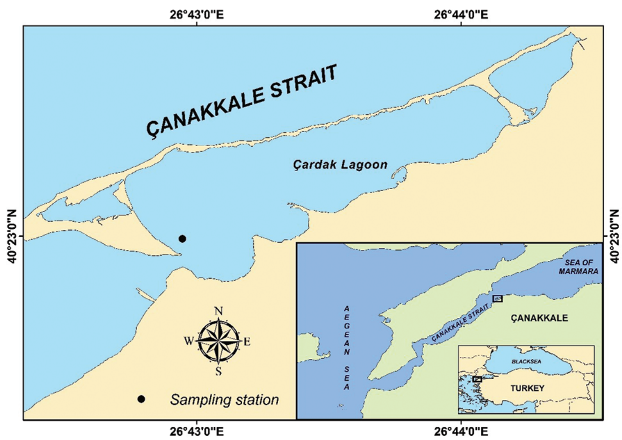

Figure 1. *Flexopecten glaber*. Map of the sampling area.

Crude protein analysis

Crude protein analysis was carried out according to the Kjeldahl method (AOAC, 2000). Calculations were made using the 6.25 nitrogen conversion factor. Dry meat samples were treated by adding 98% H_2SO_4 and a Kjeldahl tablet for 1 hour, then distilled with 0.1 M NaOH and 0.5 M boric acid. The distilled samples were titrated with 0.5 N HCl and the protein value was determined based on the amount of HCl. Protein content was expressed as percent of dry weight (dw).

Amino acid analysis

The amino acid analysis was performed by adding 20 mL of 6 N HCl to the dry meat samples and passing them through nitrogen gas before placing them in an oven at 110°C. After 24 hours, after filtering through 0.20 µm PTFE syringe filters, the samples were

Table 1. *Flexopecten glaber*. Conversion coefficients of freeze dried to wet meat.

Months	Wet meat conversion coefficients
Jul.	0.25
Aug.	0.26
Sep.	0.24
Oct.	0.26
Nov.	0.24
Dec.	0.22
Jan.	0.22
Feb.	0.25
Mar.	0.25
Apr.	0.23
May.	0.23
Jun.	0.23

derivatized using the EZ-fast kit (EZ: fast GC/FID Protein Hydrolysate Amino Acid Kit) according to the manufacturer's instruction (Phenomenex). The derivatized samples were read in the GC.

Statistical analysis

The significance of the monthly variations of protein and amino acid composition was determined using one-way analysis of variance (ANOVA). Homogeneity of variance was tested using the Levene test, and the normality of the data was tested using the Kolmogorov-Smirnov test. Differences were further analysed using the *post hoc* Tukey test. Differences with corresponding values of $p < 0.05$ were considered statistically significant.

The results were also examined using principal component analysis (PCA) using R Version 3.6.1. (R Core Team, 2020), in order to identify the amino acids that most contribute to the monthly variations of amino acid content. FactoMineR (Lê et al., 2008), Factoextra (Kassambra & Mundt, 2020) and corrplot packages (Wei & Simko, 2017) were used to conduct these analyses. The FactoMineR and Factoextra packages were used to compute principal component analysis, and the corrplot package was used to visualize the correlation matrix (Spearman correlation).

Results

Crude protein content

The monthly protein contents in freeze-dried smooth scallop meat are given in figure 2. The lowest protein

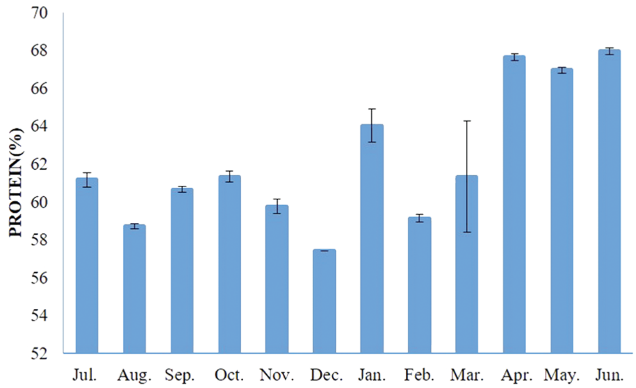

Figure 2. *Flexopecten glaber*. Monthly variations in protein content (percent dry weight) (mean ± standard deviation).

values were observed in December at 57.41%, whereas the highest protein values were observed in April at 67.62%. Although fluctuations in the protein values were not substantial, in general, low values were observed in autumn and high values were observed in summer.

Essential amino acids composition

The monthly changes in EAA concentrations are given in table 2. The most abundant EAA was phenylalanine. Its highest concentration was measured in April, whereas the lowest value was measured in November. Phenylalanine was positively correlated with lysine, but negatively correlated with leucine, histidine, tryptophan and threonine ($p < 0.05$) (Fig. 3). The monthly changes in histidine values were significant

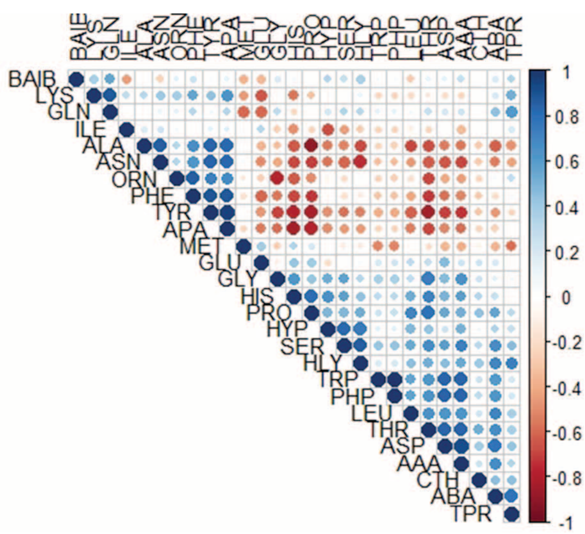

Figure 3. *Flexopecten glaber*. Pairwise correlation plot between amino acid concentrations

Table 2. *Flexopecten glaber*. Monthly variations in essential and non-essential amino acid composition (g/100g dw). [1](For each amino acid, means are given in the first line, and standard deviations in the second line).

[1]Different superscript letters within rows represent significant differences ($p < 0.05$) based on results of the *post hoc* Tukey test. (HIS: Histidine, ILE: Isoleucine, LEU: Leucine, LYS: Lysin, MET: Methionine, PHE: Phenylalanine, THR: Threonine, TRP: Tryptophan, EAA: Essential amino acids, ALA: Alanine, ASP: Aspartic acid, GLU: Glutamic acid, GLY: Glycine, SER: Serine, TYR: Tyrosine, PRO: Proline, ASN: Aspargine, ORN: Ornithine, GLN: Glutamine, ABA: α-aminobutyric acid, BAIB: β-aminoisobutyric acid, TPR: Thiaproline , HYP: Hydroxyproline, AAA: α-aminoadipic acid , APA: α-aminopimelic acid, HLY: Hydroxicillin, PHP: Prolin-Hydroxyproline, CTH:Cystathionine, NEAA: Non Essential Amino Acids, EAA/NEAA: Essential Amino Acid/Non Essential Amino Acid).

[2]N.D.: Non detected.

Amino Acid[2]	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May.**	**Jun.**
HIS	2.86^{ab}	4.53^{ab}	3.92^{ab}	5.42^{b}	3.77^{ab}	4.86^{ab}	2.56^{ab}	2.74^{ab}	1.76^{a}	1.80^{a}	1.69^{a}	2.31^{ab}
	0.73	1.13	0.90	1.27	0.90	1.12	0.00	0.0	0.00	0.00	0.00	0.00
ILE	0.28^{a}	0.14^{a}	0.08^{a}	0.10^{a}	0.09^{a}	0.07^{a}	0.24^{a}	0.08^{a}	0.18^{a}	0.09^{a}	0.36^{a}	0.11^{a}
	0.07	0.04	0.02	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
LEU	3.22^{a}	3.28^{a}	3.46^{a}	3.23^{a}	3.13^{a}	3.27^{a}	3.16^{a}	2.68^{a}	2.90^{a}	3.10^{a}	3.03^{a}	3.23^{a}
	0.82	9.82	0.80	0.76	0.75	0.75	0.00	0.00	0.00	0.00	0.00	0.00
LYS	0.28^{a}	0.12^{a}	0.08^{a}	0.06^{a}	0.02^{a}	0.06^{a}	0.16^{a}	0.15^{a}	0.19^{a}	0.21^{a}	0.07^{a}	0.18^{a}
	0.07	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MET	1.50^{ab}	1.85^{ab}	1.40^{a}	2.84^{b}	2.13^{ab}	2.11^{ab}	2.07^{ab}	1.77^{ab}	2.03^{ab}	1.78^{ab}	2.08^{ab}	2.11^{ab}
	0.38	0.46	0.32	0.67	0.51	0.49	0.00	0.00	0.00	0.00	0.00	0.00
PHE	7.85^{a}	7.10^{a}	7.43^{a}	7.18^{a}	6.86^{a}	7.58^{a}	9.86^{a}	10.22^{a}	8.74^{a}	12.83^{a}	8.37^{a}	10.20^{a}
	2.00	1.78	1.70	1.69	1.64	1.74	0.00	0.00	0.00	0.00	0.00	0.00
THR	1.52^{bcd}	1.70^{d}	1.65^{cd}	1.46^{abcd}	1.34^{abcd}	1.33^{abcd}	1.17^{abc}	1.12^{ab}	1.23^{abd}	1.01^{a}	1.00^{a}	1.18^{ab}
	0.39	0.43	0.38	0.35	0.32	0.31	0.00	0.00	0.00	0.00	0.00	0.00
TRP	N.D	0.01^{ab}	0.03^{b}	N.D.	N.D	N.D	N.D	N.D.	N.D.	N.D.	N.D.	N.D.
	N.D.	0.00	0.01	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Total EAA	**17.52^{a}**	**18.75^{a}**	**18.05^{a}**	**20.29^{a}**	**17.34^{a}**	**19.28^{a}**	**19.22^{a}**	**18.77^{a}**	**17.03^{a}**	**20.82^{a}**	**16.60^{a}**	**19.31^{a}**
	4.47	4.69	4.15	4.77	4.15	4.44	0.00	0.00	0.00	0.00	0.00	0.00
ALA	3.06^{a}	3.10^{a}	3.35^{ab}	3.29^{ab}	3.08^{a}	2.99^{a}	4.56^{c}	4.58^{c}	4.08^{bc}	3.79^{abc}	3.80^{abc}	3.78^{abc}
	0.78	0.78	0.77	0.77	0.74	0.69	0.00	0.00	0.00	0.00	0.00	0.00
ASP	0.90^{ab}	1.08^{ab}	1.47^{b}	0.86^{ab}	0.55^{ab}	0.46^{ab}	0.37^{ab}	0.40^{ab}	0.45^{ab}	0.43^{ab}	0.59^{ab}	0.35^{a}
	0.23	0.27	0.33	0.20	0.13	0.10	0.00	0.00	0.00	0.00	0.00	0.00
GLU	2.52^{a}	3.76^{a}	3.46^{a}	4.64^{a}	3.20^{a}	2.74^{a}	2.50^{a}	2.21^{a}	1.97^{a}	1.88^{a}	5.11^{a}	2.11^{a}
	0.65	0.94	0.80	1.10	0.76	0.63	0.00	0.00	0.00	0.00	0.00	0.00
GLY	9.04^{d}	8.64^{d}	8.92^{d}	7.76^{bcd}	8.28^{cd}	8.79^{d}	8.33^{cd}	8.10^{bcd}	7.53^{abcd}	6.00^{abc}	5.22^{a}	5.80^{ab}
	2.30	2.16	2.05	1.82	1.99	2.02	0.00	0.00	0.00	0.00	0.00	0.00
SER	0.81^{a}	0.89^{a}	0.91^{a}	0.91^{a}	0.69^{a}	0.72^{a}	0.64^{a}	0.49^{a}	0.62^{a}	0.91^{a}	0.28^{a}	0.42^{a}
	0.21	0.22	0.21	0.21	0.16	0.17	0.00	0.00	0.00	0.00	0.00	0.00
TYR	3.44^{a}	3.27^{a}	3.23^{a}	3.44^{a}	3.00^{a}	3.68^{a}	8.43^{ab}	9.66^{b}	7.95^{ab}	10.12^{b}	7.96^{ab}	9.80^{b}
	0.87	0.82	0.74	0.81	0.72	0.85	0.00	0.00	0.00	0.00	0.00	0.00
PRO	2.55^{ab}	2.78^{b}	2.42^{ab}	2.71^{ab}	2.44^{ab}	2.68^{ab}	1.90^{ab}	1.83^{a}	2.04^{ab}	1.95^{ab}	2.07^{ab}	2.41^{ab}
	0.65	0.69	0.56	0.64	0.59	0.62	0.00	0.00	0.00	0.00	0.00	0.00

Table 2. Continued

ASN	0.19^{a}	0.13^{a}	0.20^{a}	0.11^{a}	0.13^{a}	0.19^{a}	1.50^{a}	0.94^{a}	1.18^{a}	0.58^{a}	0.65^{a}	1.37^{a}
	0.05	0.03	0.05	0.03	0.03	0.04	0.00	0.00	0.00	0.00	0.00	0.00
ORN	0.10^{a}	0.04^{a}	0.07^{a}	0.05^{a}	0.04^{a}	0.07^{a}	0.12^{a}	0.15^{a}	0.07^{a}	0.56^{a}	0.29^{a}	0.31^{a}
	0.02	0.01	0.02	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00
GLN	1.03^{a}	0.58^{a}	0.65^{a}	0.44^{a}	0.32^{a}	0.41^{a}	0.57^{a}	0.63^{a}	0.60^{a}	0.70^{a}	0.24^{a}	0.68^{a}
	0.27	0.14	0.15	0.10	0.08	0.09	0.00	0.00	0.00	0.00	0.00	0.00
ABA	3.01^{a}	3.10^{a}	3.12^{a}	2.84^{a}	2.61^{a}	2.66^{a}	2.51^{a}	2.41^{a}	2.69^{a}	2.95^{a}	2.67^{a}	2.78^{a}
	0.77	0.78	0.72	0.67	0.63	0.61	0.00	0.00	0.00	0.00	0.00	0.00
BAIB	6.17^{a}	5.12^{a}	5.25^{a}	5.17^{a}	4.75^{a}	4.61^{a}	3.24^{a}	7.24^{a}	4.48^{a}	5.99^{a}	3.67^{a}	5.07^{a}
	1.57	1.28	1.21	1.21	1.14	1.06	0.00	0.00	0.00	0.00	0.00	0.00
TPR	0.29^{a}	0.24^{a}	0.13^{a}	0.04^{a}	0.07^{a}	0.07^{a}	0.03^{a}	0.03^{a}	0.06^{a}	0.23^{a}	0.10^{a}	0.09^{a}
	0.07	0.06	0.03	0.01	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00
HYP	2.88^{a}	2.85^{a}	2.90^{a}	3.00^{a}	2.93^{a}	3.20^{a}	2.70^{a}	2.64^{a}	2.48^{a}	3.10^{a}	2.16^{a}	2.59^{a}
	0.74	0.06	0.66	0.71	0.70	0.74	0.00	0.00	0.00	0.00	0.00	0.00
AAA	5.10^{ab}	5.47^{ab}	9.85^{b}	4.68^{ab}	4.43^{ab}	3.32^{ab}	1.81^{a}	2.53^{a}	1.72^{a}	2.71^{a}	0.86^{a}	1.09^{a}
	1.31	0.06	2.24	1.10	1.07	0.76	0.00	0.00	0.00	0.00	0.00	0.00
APA	0.24^{a}	0.21^{a}	0.23^{a}	0.17^{a}	0.14^{a}	0.16^{a}	0.35^{a}	0.39^{a}	0.37^{a}	0.41^{a}	0.31^{a}	0.41^{a}
	0.06	0.06	0.05	0.04	0.03	0.04	0.00	0.00	0.00	0.00	0.00	0.00
HLY	0.40	0.44	0.25	0.33	0.27	0.27	0.06	0.06	0.11	0.48	0.04	0.04
	0.10	0.06	0.06	0.08	0.06	0.06	0.00	0.00	0.00	0.00	0.00	0.00
PHP	N.D.	0.09^{a}	0.23^{a}	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	N.D.	0.06	0.05	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
CTH	N.D.	0.25	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	N.D.	0.06	N.D.	N.D	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Total NEAA	**41.71^{a}**	**42.04^{a}**	**46.68^{a}**	**40.43^{a}**	**36.91^{a}**	**37.00^{a}**	**39.64^{a}**	**44.29^{a}**	**38.41^{a}**	**42.79^{a}**	**36.03^{a}**	**39.12^{a}**
EAA/NEAA	0.42^{a}	0.45^{a}	0.39^{a}	0.50^{a}	0.47^{a}	0.52^{a}	0.48^{a}	0.43^{a}	0.44^{a}	0.49^{a}	0.46^{a}	0.50^{a}

(ANOVA, $p < 0.05$), with the highest amount being found in December. Histidine was positively correlated with threonine and leucine, but negatively correlated with lysine and phenylalanine ($p < 0.05$) (Fig. 3). Leucine content was highest in autumn. Leucine was positively correlated with histidine, threonine, tryptophan and lysin, but negatively correlated with phenylalanine ($p < 0.05$) (Fig. 3). The highest of methionine was measured in October, whereas the lowest value was observed in September. Methionine was negatively correlated with tryptophan ($p < 0.05$) (Fig. 3).

According to the PCA, the contribution of tryptophan, threonine, histidine, methionine amino acids among other EAA was higher. January was characterized by higher content in isoleucine, February, April and June by lysine and phenylalanine, August by histidine, September, November and December by tryptophan, threonine and leucine (Fig. 4).

Non-essential amino acid composition

The changes in NEAA values in smooth scallop samples are given in Table 2. A high level of glycine was found in NEAAs, followed by tyrosine, β-aminoisobutyric acid, and alanine. The highest NEAA values were observed in September, whereas the lowest were observed in December. Alanine was positively correlated with asparagine, tyrosine, α-aminoadipic acid and phenyl-alanine, but negatively correlated with serine, thiaproline, hydroxicillin, aspartic acid, proline, α-aminobutyric acid, histidine, leucine and threonine ($p < 0.05$) (Fig. 3). Glycine was positively correlated with α-aminoadipic acid, serine, proline-hydroxyproline, aspartic acid, threonine, histidine

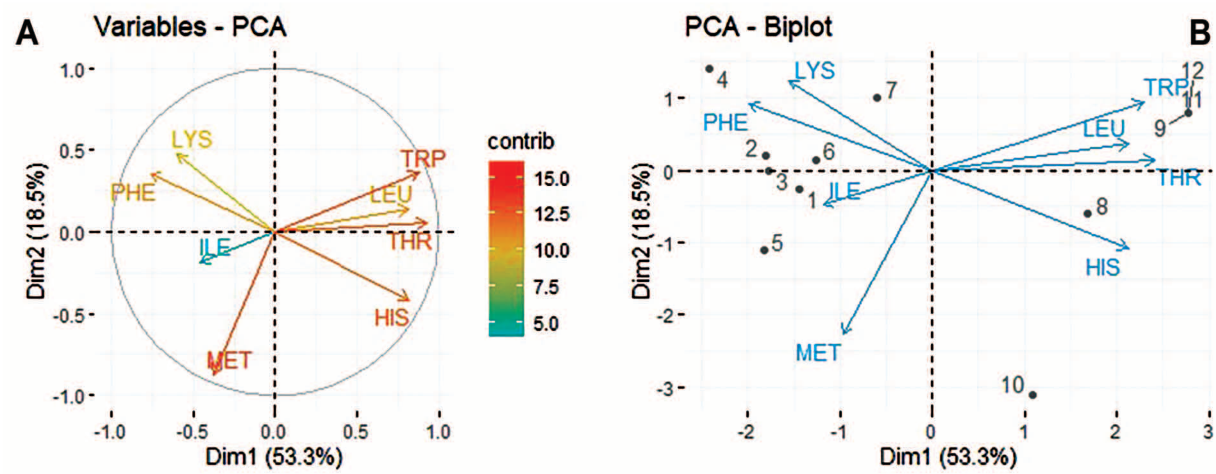

Figure 4. *Flexopecten glaber*. Principal component analysis (PCA) of the composition of essential amino acids. A. Ordination plot of the variables showing the contribution of each amino acid. B. Ordination biplot. HIS: Histidine, ILE: Isoleucine, LEU: Leucine, LYS: Lysin, MET: Methionine, PHE: Phenylalanine, THR: Threonine, TRP: Tryptophan, 1: January, 2: February, 3: March, 4: April, 5: May, 6: June, 7: July, 8: August, 9: September, 10: October, 11: November, 12: December.

and tryptophan, but negatively correlated with α-aminopimelic acid, tyrosine, ornithine and phenylalanine ($p < 0.05$) (Fig. 3). Tyrosine was positively correlated with α-aminopimelic acid, asparagine, ornithine and alanine, but negatively correlated with hydroxicillin, proline-hydroxyproline, α-aminobutyric acid, proline, α-aminoadipic acid, glutamic acid, serine, glycine and, aspartic acid ($p < 0.05$) (Fig. 3). β-aminoisobutyric acid was positively correlated with glutamine, but negatively correlated with isoleucine ($p < 0.05$) (Fig. 3).

According to the PCA, the contribution of α-aminopimelic acid, thiaprolin, aspartic acid amino acids in NEAA were higher. Furthermore proximity were observed in February and June with tyrosine and asparagine, in March with α-aminobutyric acid, in August, September, November and December with hydroxyproline, aspartic acid, proline-hydroxyproline,

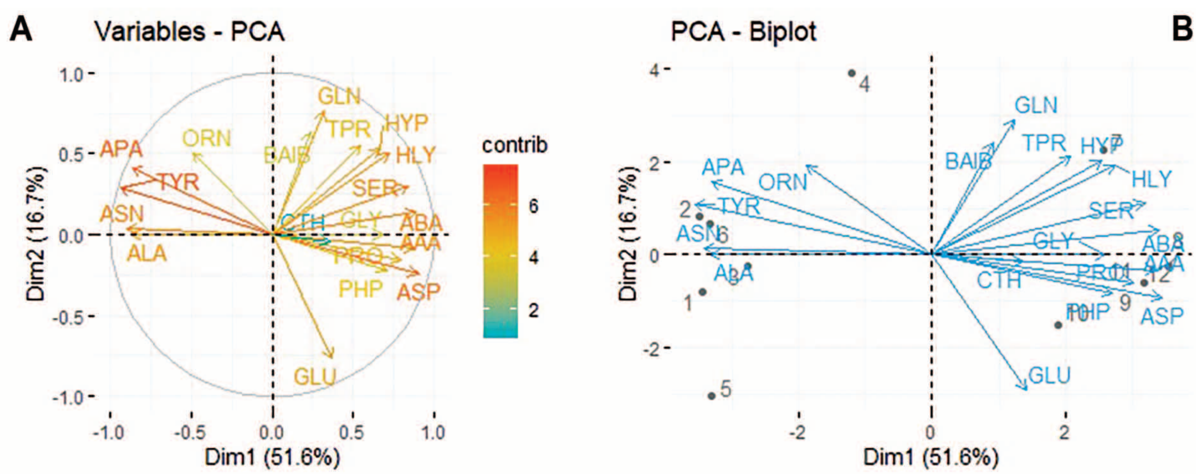

Figure 5. *Flexopecten glaber*. Principal component analysis (PCA) of the composition of non-essential amino acids. A. Ordination plot of the variables showing the contribution of each amino acid. B. Ordination biplot. ALA: Alanine, ASP: Aspartic acid, GLU: Glutamic acid, GLY: Glycine, SER: Serine, TYR: Tyrosine, PRO: Proline, ASN: Aspargine, ORN: Ornithine, GLN: Glutamine, ABA: α-aminobutyric acid, BAIB: β-aminoisobutyric acid, TPR: Thiaproline , HYP: Hydroxyproline, AAA: α-aminoadipic acid, APA: α-aminopimelic acid, HLY: Hydroxicillin, PHP: Prolin-Hydroxyproline, CTH: Cystathionine, 1: January, 2: February, 3: March, 4: April, 5: May, 6: June, 7: July, 8: August, 9: September, 10: October, 11: November, 12: December.

proline, α-aminoadipic acid and α-aminobutyric acid (Fig. 5).

Discussion

Previous studies have shown that monthly changes in protein content is associated with size, species, genetic traits, temperature, nutrient amount and reproductive period (Baptista et al., 2014; Inyang & Effong, 2017; Acarli et al., 2018). In particular, during gametogenesis, proteins are used as an alternative energy source in some bivalve species when carbohydrate and fat reserves are exhausted (Acarli et al., 2015; Inyang & Effong, 2017). Furthermore, since bivalves use proteins to form oocytes (Holland, 1978), reproductive activity affects protein levels (Galap et al., 1997; Yıldız et al., 2011). In *F. glaber*, Marceta et al. (2011 & 2016) determined that the gonadosomatic index was the highest in June in the North Adriatic Sea, and reported that spawning occurred during summer between July and September, and that the resting period was between October and December. In the present study, considering the visible changes in the gonad of *F. glaber* , the fullness of the gonad, and especially the egg dispersal in the gonad region during the process, it can be suggested that the gonads were mature from March to June and from August to September. Therefore, we hypothesized that the observed changes in the protein content may be related to reproduction. The increase in the protein content in *F. glaber* from March to June is concomitant to increasing reproductive activity, whereas the decrease from August to September can be associated with the transition to the spawning and resting phases.

The ratio of EAAs to NEAAs in food is defined as an indicator of the “ideal protein” that optimizes human health and indicates protein utilization (Wu, 2009). A ratio of EAAs to NEAAs higher than 1 indicates that it is a well-balanced source of protein (Chakraborty et al., 2016). For example, the EAA/NEAA ratio was higher than 1 in the bivalves *Senilia senilis* (Linnaeus, 1758) (Inyang & Effong, 2017) and *Crassostrea madrasensis* (Preston, 1916) (Chakraborty et al., 2016), but lower than 1 in *Mytilus coruscus* Gould, 1861 (Li et al., 2010), *Ensis siliqua* (Linnaeus, 1758) (Baptista et al., 2014), *Thais caelifera* (Lamarck, 1822) and *Ostrea tulipa* Lamarck, 1819 (Inyang & Effong, 2017). In the present study, the EAA/NEAA ratio ranged between 0.39 and 0.52 for *F. glaber*. In this context, the EAA/NEAA ratio may vary depending on the species, and as a consequence influence the nutritional quality of the species. Proteins differ according to the composition of the amino acids that form them, and the amount and quality of EAAs determine the quality of the proteins (Pigott & Tucker, 1990). Bivalve species are commonly rich in EAAs, also EAA play a role in the growth, reproduction and the synthesis of vitamins (Abirami et al., 2015; Inyang & Effong, 2017). For humans, there are 8 EAAs: lysine, methionine, threonine, tryptophan, isoleucine, leucine, phenylalanine, and valine (Erkan et al., 2010). In this study, all these EAA except valine were detected in smooth scallops during the whole year. Moreover, 31.5% (18.58 ± 2.94 g.100 g^{-1} dw, 2.22 ± 1.89 g.100 g^{-1} ww) of the total amount of amino acids in smooth scallops was measured as EAA. This value has been reported as 8.06 g.100 g^{-1} ww for *T. caelifera*, 15.45 g.100 g^{-1} ww for *O. tulipa* and 23.06 g.100 g^{-1} ww in *S. senilis* (Inyang & Effong, 2017) while it has been reported as 35.4% in *D. incarnatus* (Periyasamy et al., 2014).

The required amount of lysine for humans is 1-1.5 g per day (Özden & Erkan, 2011). Lysine deficiency, in turn, causes vitamin B deficiency (Özden & Erkan, 2011). In the present study, the values found in smooth scallops were lower than those reported by Özden & Erkan (2011) and Inyang & Effong (2017). In this study, there was a positive correlation of histidine with threonine and leucine, whereas there was a negative correlation of histidine with protein, lysine, and phenylalanine. Histidine is a semi-essential amino acid, synthesized from methionine and phenylalanine (Belitz et al., 2004). Confirming this, a negative correlation was found between histidine and phenylalanine. The daily histidine intake in infants is recommended as 33 mg/kg (HMDB, 2019). The histidine level in the present study was 3.19 ± 1.28 g.100 g^{-1} dw (0.50 ± 0.54 g.100 g^{-1} ww). Such a value was high, and suggested that the consumption of 6.6 g.kg^{-1} of smooth scallop will meet the daily requirement. A 1 g daily use of threonine is recommended in the treatment of genetic spasticity disorders (HMDB, 2019). It may be considered that threonine needs will be met with 555 g of smooth scallop consumption per day.

Species, environmental conditions (temperature, salinity, nutrients, etc.) and reproductive cycles have an effect on the changes in amino acid values (Inyang & Effong, 2017; Effendy et al., 2018). It has been observed that the seasonal variations in the amount of some amino acids such as leucine, threonine and lysine have a strong relationship with the spawning period, increasing in the spawning period and decreasing afterwards (Wu et al., 2013). Baptista et al. (2014) stated that the leucine concentration in *E. marginatus* increased with spawning, which can be associated with the possibility of leucine rejoining the formation of the gonad after spawning. In the present study, leucine was positively correlated with threonine, tryptophan and lysine. Our results agreed with Baptista et al. (2014).

The glycine values observed in smooth scallops in the present study were lower than those reported by Manthey-Karl et al. (2015) for *Pecten maximus* (Linnaeus, 1758), but higher than those reported by Inyang & Effong (2017) for *T. caelifera*, *S. senilis* and *O. tulipa*. Glycine is synthesized from serine, threonine, choline, and hydroxyproline (Wang et al., 2014). Glycine was positively correlated with serine, proline-hydroxyproline and threonine. Chakraborty et al. (2016) have stated that in *C. madrasensis,* the low glycine content during summer was associated with this fact. Glycine is effective in resisting salinity and adverse environmental conditions during the summer, therefore, protecting cells from osmotic damage (Eklund et al., 2005). In the present study, glycine levels in *F. glaber* were higher in the summer, but lower in the spring. Baptista et al. (2014) have stated that the glutamic acid value in *Ensis marginatus* (Pennant, 1777) increased with spawning, as is the case with leucine, which was related to the possibility of rejoining the gonad formation after spawning. Considering the macroscopic findings (volume increase of the gonad, clarity and brightness of the colour and liquefaction of the gonad) and the fact that the gonads are mature during two periods (March to June and August to September), our results agreed with those reported by Baptista et al. (2014) in *E. marginatus*.

Conclusion

According to our results, we suggest that smooth scallop meat could be an alternative food source to other seafood in terms of protein content and amino acid composition, and that its consumption will be beneficial in terms of meeting nutrition requirements for human. With its content of protein, and particular amino acids, like phenylalanine and glycine, which are nowadays sought in dietary regulation, this bivalve could be an alternative to mussels. These results provide valuable information for both smooth scallop producers and consumers. For smooth scallop producers, the data obtained may be useful for indicating the timescale when the smooth scallop meat is most suitable in terms of amino acid and protein contents. For consumers, the data obtained can be used as a guide for the most suitable seasons for consumption according to nutritional requirements. Especially in terms of histidine, autumn is the most suitable time for consumption, while summer and autumn are most suitable in terms of threonine.

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