

Monthly variation of micro- and macro-element composition in smooth scallop, *Flexopecten glaber* (Linnaeus, 1758), from the Çardak Lagoon (Çanakkale Strait, Turkey)

Çardak Lagünü'ndeki (Çanakkale Boğazı, Türkiye) deniz tarağının *Flexopecten glaber* (Linnaeus, 1758), mikro ve makro element kompozisyonundaki aylık değişimler

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Abstract: The present study investigated the total elemental composition (Fe, Cu, Mn, Zn, Al, S, B, Na, Mg, K, Ca, P, S) in smooth scallop (*Flexopecten glaber*) meat collected monthly in the Çardak Lagoon (Turkey) in 2017- 2018. Considering the distribution of elements in terms of quantity during the year, the elements were sorted as S> Na> K> P> Mg> Ca> Fe> Zn> Mn> Al> B> Cu> Se and the heavy metals were below the detection limit. Although the elements were at their highest values during autumn and summer, they were at their lowest values during spring and winter. The differences between the months in terms of Fe, Mn, Mg, and Ca elements were found to be statistically significant ($p < 0.05$). It was determined that the element composition of smooth scallop meat was suitable for consumption in terms of the area where it is collected and is beneficial for health when consumed in the amounts recommended by FAO/WHO, and CODEX. The Hazard Quotient (THQ) and the Hazard Index (HI), which was conducted to evaluate the health risks of consuming smooth scallop, were found below 1 all months. For this reason, smooth scallop consumption in this region does not have any negative effects on human health.

Keywords: *Flexopecten glaber*, smooth scallop, element, Çardak Lagoon, Çanakkale Strait

Öz: Bu çalışmada Çardak Lagünü'nden (Türkiye) 2017- 2018 tarihleri arasında bir yıl boyunca aylık olarak toplanan smooth scallop (*Flexopecten glaber*) etinin toplam element kompozisyonu (Fe, Cu, Mn, Zn, Al, Se, B, Na, Mg, K, Ca, P, S) belirlenmiştir. Elementlerin miktar açısından yıl içindeki dağılımına bakıldığında S> Na> K> P> Mg> Ca> Fe> Zn> Mn> Al> B> Cu> Se sıralamasında olduğu, ağır metallerin ise dedeksiyon limitinin altında olduğu gözlemlenmiştir. Elementler sonbahar ve yaz döneminde en yüksek değerlerde bulunmasına karşın, ilkbahar ve kış döneminde en düşük değerlerde gözlemlenmiştir. Fe, Mn, Mg ve Ca elementlerinde aylar arasındaki farklar istatistiksel olarak önemli bulunmuştur ($p < 0.05$). Toplandığı bölge bakımından deniz tarağı etinin element kompozisyonunun tüketim için uygun olduğu ve FAO/WHO, CODEX tarafından tavsiye edilen miktarlarda tüketildiğinde sağlığa yararlı olduğu tespit edilmiştir. Deniz tarağı tüketiminin sağlık açısından risklerini değerlendirmek amacıyla yapılan Hedef Tehlike Katsayısı (THQ) ve Tehlike İndeksi (HI) tüm aylarda 1'in altında bulunmuştur. Bu nedenle bu bölgedeki deniz tarağı tüketiminin insan sağlığına olumsuz etkisi bulunmamaktadır.

Anahtar kelimeler: *Flexopecten glaber*, deniz tarağı, element, Çardak Lagünü, Çanakkale Boğazı

INTRODUCTION

Seawater, which forms oceans and seas, covers more than 70% of the earth's surface. Also, seawater is a mixture of 96.5% water, 2.5% salt and contains dissolved inorganic and organic substances and several atmospheric gases. Seawater is rich in elements (Sharp and Bryne *et al.*, 2020). Elements reach the sea from various sources. These are divided into natural resources and anthropogenic resources. Natural resources include mineral deposits, erosion of soil and rocks, dust caused by wind, volcanic activities, atmospheric and forest fires. Those anthropogenic resources include waste products, household wastes, pesticides, mines, petroleum refineries, protective paints, which are formed as a result of the use of elements and compounds in the industry (Ünsal, 2004). Elements that reach the seas from these

sources are soluble in seawater or are present in the form of particles. Soluble ones are in the form of free metal ions or unstable organic and inorganic compounds (Çetingül and Aysel, 1998; Ünsal, 2004). Sea bottoms are areas of continuous sediment formation. Some of the sediments are materials transported by rivers, winds, and glaciers to the sea, and most of the sediments are the remains of marine creatures (Akkan, 1981). Aquatic organisms can take elements directly from the body surface and gills, as well as through digestion (Phillips and Rainbow, 1994; Bat and Raffaelli, 1998).

Lagoons are ecotones between freshwater, marine, and terrestrial biotopes (Ustaoglu *et al.*, 2012; Maanan *et al.*,

2015; Botello *et al.*, 2018; Kükre *et al.*, 2020). Lagoons are connected to the sea via one or more canals. The water exchange with the sea and the transport of nutrients with it occur through tides, river flow, wind, and waves (Larson, 2012; Sevgi and Ulutarhan-Süzer, 2019). Due to the shallow transitional environments of lagoons such as rivers, streams, groundwaters and currents in lagoons, and also due to the influence of coastal geomorphological processes, hydrological processes, natural vegetation, and land use in the basin (Ustaoğlu *et al.*, 2012), the physicochemical parameters frequently change. This affects the physiology and metal bioaccumulation in organisms distributed in lagoons (McLusky *et al.*, 1986; Dame, 1996; Ulutarhan *et al.*, 2019). Lagoons are among the most productive marine ecosystems in the world, serving as nutrition, habitat, migration routes, and nursery areas for many organisms such as phytoplankton, diatom, dinoflagellate, algae, fish, and bivalves (Din, 1992; Balls *et al.*, 1997; Chapman and Wang, 2001). The Çardak lagoon chosen as a study area is abundant in terms of many economic fish species such as Mullet (*Mugil* sp.), Gilthead seabream (*Sparus aurata*), Scad (*Trachurus* sp.), Bluefish (*Pomatomus saltatrix*), eel fish (*Anguilla* sp.), picarel (*Spicara smaris*), common sole (*Solea* sp.), sparid fish (*Sarpa salpa*), striped sea bream (*Lithognathus mormyrus*), garfish (*Belone belone*), twaite shad (*Livoneca punctata*), flounder (*Platichthys flesus*) and bivalve species such as Mediterranean mussel (*Mytilus galloprovincialis*), manila clam (*Ruditapes philippinarum*), carpet shell clam, (*Ruditapes decussatus*), flat oyster (*Ostrea edulis*), razor clam (*Ensis* sp.), venerid clam (*Venus gallina*), lagoon cockle (*Cerastoderma glaucum*) (Vural and Acarli, 2018).

Smooth scallop (*Flexopecten glaber*) is one of the bivalve organisms within the mollusks and is included in the *Pectinidae* order. *F. glaber* is distributed from the eastern Atlantic, Mediterranean, Black Sea, and Portugal to Morocco while in Turkey, it is seen as dense stocks from the south of Marmara, along the Aegean Sea, and throughout the Mediterranean (Aquamaps, 2019).

Bivalves are important marine organisms due to their nutritional value, taste, and reasonable selling prices (Orban *et al.*, 2002; Orban *et al.*, 2007). They have a rich nutritional composition, including high protein content, essential amino acids, low-fat content, high levels of ω 3 fatty acids, elements, and antioxidants (Orban *et al.*, 2002; Orban *et al.*, 2007; Prato *et al.*, 2019).

Microelements are accumulated in marine organisms (Plessi *et al.*, 2001) and transferred to humans through the food chain (Gökoğlu *et al.*, 2008). Microelements are

especially of important in infants and children (WHO, 2006). Elements such as iron (Fe), copper (Cu), zinc (Zn), and manganese (Mn) are essential elements as they play an important role in biological systems (Hogstrand and Haux, 1991), however, their excessive consumption is toxic (Tarley *et al.*, 2001). Generally, bivalves accumulate certain elements, especially zinc (Lök *et al.*, 2010). Storelli *et al.* (2000) have reported that mollusks have a higher amount of Zn compared to fish species found in the Mediterranean. Manthey-Karl *et al.* (2015) have reported that smooth scallop meat is a good source of Zn. El Shenawy *et al.* (2016) observed that Al is dominant in sediments and bivalves. In humans, an average of 4% aluminum (Al) taken with nutrition is absorbed by the intestines and accumulates in bones, liver, lung, thyroid glands, and brain (Hellström-Westas and Rosen, 2006).

Sodium (Na), Magnesium (Mg), Potassium (K), Calcium (Ca), Phosphorus (P), and Sulfur (S) are macro elements. Na is an important element in the regulation of osmotic pressure (Tapiero *et al.*, 2003; Yaşar and Melek, 2003), stimulation of nerves, and continuity of nerve and muscle functions. Also, Na plays a role in bone development together with Ca. Bivalves contain higher levels of Na than fish species (Spanish mackerel, Gray eel-catfish, Longtail shad; Cuttlefish, Prawn) (Nurnadia *et al.*, 2013), while sea species contain higher levels of Na than freshwater species (Sidwell *et al.*, 1977). K is one of the vital elements for humans. Of the K in the body, 98% is found inside the cell walls. K, together with Na, is responsible for the water balance in the body, in the passage of food into the cell, in the transmission of messages in the nervous system, in the formation of tissues such as bones, teeth, red blood cells, and muscles, and it maintains the healthy structure of the heart and other muscles. Also, K has beneficial effects in the development of bones together with Ca (Karadeniz, 2004; İnan and Gül, 2001; Cashman, 2006). It was determined that the macro element with the highest ratio in smooth scallop meat is usually K (Bilandzic *et al.*, 2015, Manthey-Karl *et al.*, 2015).

There are studies on the elemental composition of smooth scallop meat (Özden and Erkan, 2011; Berik *et al.*, 2017; Prato *et al.*, 2019a; Prato *et al.*, 2019b). However, studies on the monthly element composition are limited (Prato *et al.*, 2019a). Therefore, the present study aimed to monthly determine the element content of the meat of smooth scallop (*F. glaber*), one of the economic bivalves collected from the Çanakkale Strait Çardak lagoon in the Turkish Straits System, and also to determine its compliance with the maximum limits

determined by health organizations. In addition, in this study, it was aimed to evaluate the potential health risk that may occur in case of consumption by adults by determining the Target Hazard Quotient (THQ) and Hazard Index (HI) values for the general population, taking into account the consumption frequency of the smooth scallop.

MATERIAL AND METHODS

Smooth scallop samples (53.95 ± 3.70 mm in length) were collected by hand monthly between July 2017 and June 2018 in the Canakkale Province, Lapseki district, Çardak Lagoon in Turkey, ($40^{\circ} 22' 56''\text{N}$, $21^{\circ} 42' 58''\text{E}$) (Figure 1). Çardak lagoon consists of 3 parts: Burunucu lagoon, Buruniçi lagoon and Ortagöl. The lagoon is a 180 ha saltwater lagoon located near the village of Çardak (Lapseki-Canakkale) on the southern coast of Marmara Sea. It is a lagoon with an average depth of 1.5 m (GTHB, 1997). The lagoon is under the influence of the sea, with its deep and open passage. There are many fish and bivalve species in the lagoon. Throughout the study, 30 smooth scallops per month were brought to the laboratory. Fouling organisms adhering on the smooth scallops were removed using a knife and the meat content of the smooth scallop was freeze dried after separating the meat from the shell parts.

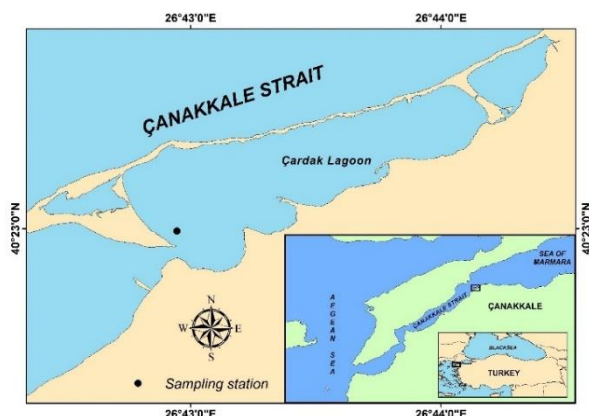


Figure 1. Map showing the sampling area Çardak Lagoon

A 0.5 g of dry smooth scallop meat and 10 ml of HNO_3 mixture were dissolved by burning in a microwave incinerator. It was then allowed to cool and filtered with distilled water. SpectroBlue inductively coupled plasma optical emission spectrometry (ICP-OES) was used to measure the element concentrations in smooth scallop meat after closed-vessel microwave digestion (EPA, 1994). Element content was expressed as percent of dry weight (dw).

Freeze-dried meat of the scallops was used to determine the element compositions. The dry weight of element concentration (mg/g) was converted to wet weight using to calculate the hazard quotient (THQ) and hazard index (HI). 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).

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

Months	Wet meat conversion coefficients
July	0.25
August	0.26
September	0.24
October	0.26
November	0.24
December	0.22
January	0.22
February	0.25
March	0.25
April	0.23
May	0.23
June	0.23

The values of element in smooth scallop meat were used to calculate the estimated daily intake of elements (EDI), and target hazard quotients (THQ), hazard index (HI) separately for adult individuals. In this evaluation, 70 kg of body weight refers to adult people (Yaman *et al.* 2014). The bivalve consumption rate in Turkey in 2010 is 1 g/ person-day (FAO, 2010).

Edible Daily Intake (EDI)

The EDI value was calculated with the following equation (Javed and Usmani, 2016; Alkan *et al.*, 2020; Tokatlı and Ustaoglu, 2021):

$$EDI = \frac{C_{element} \times D_{food\ intake}}{BW}$$

$C_{element}$ = Element concentration in smooth scallop wet weight (mg/kg),

$D_{food\ intake}$ = Daily ingestion rate (kg/person.day) 1 g for bivalve)

BW= Average body weight (70 kg for adults).

Target Hazard Quotient (THQ)

The THQ is an estimation of the non-carcinogenic risk level and is used in its calculation with the following equation (USEPA,2019a; 2019b):

$$THQ = \frac{EDI}{RfDo \times AT}$$

RfD: Oral referans dose (mg/kg/day) (Table 2)

AT: Average exposure time for non-carcinogenic effects (365 days/year x ED)

ED: Exposure duration (70 years for a person is assumed in this study, equivalent to the average lifetimes),

HQ is categorized into six classes: $HQ < 1$ (no health risk); $1 < HQ < 1.5$ (low health risk); $1.5 < HQ < 2$ (medium-low health

risk); $2 < HQ < 2.5$ (medium risk); $2.5 < HQ < 3$ (next higher risk); $3 < HQ$ (high risk) (USEPA, 1989; Çulha *et al.*, 2016; Alkan *et al.*, 2020).

Hazard Index (HI)

The HI can be calculated by the sum of the target hazard quotients of each metal (USEPA, 1989, 2011).

$$HI = \sum THQ$$

The significance of the monthly variations of element composition was determined using the one-way analysis of variance (ANOVA). Homogeneity of variance was determined using the Levene test. Investigation of the normality of data was carried out using the Kolmogorov-Smirnov test. Differences were analyzed using the post hoc Tukey test. Differences with 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., in order to identify the element that most contributes to the monthly variations of element content. PCA-based Biplots (Gabriel, 1971) were made for each element separately. PCA transformed the raw data into unit-less variables and also distribute variability into different factors or principal components. Biplot was drawn by using principal factors, which have most of the variability. Biplot was two dimensional scatter diagram that depicted the scattering pattern of elements and months. The method has been used to display objects and variables on the same graph in principal components analysis, row and column factors in correspondence analysis of two-way contingency tables, and detect interaction in two-way analysis of variance tables (Gower and Hand, 1996). Proximity between elements or months may be gleaned from these types of plots. Also, it is commonly used to interpret the axes in the biplot and treat the coordinates as scores on these axes. In the correlation analysis graphs, dark colors indicate a very high relationship and red colors indicate a negative relationship. As the darkness of the color increases, the strength of the relationship increases. As the color approaches white, the contribution value approaches 0.

RESULTS

The monthly changes in element concentrations are given in Table 2. The most abundant microelement was Fe, followed by Zn, Mn, and Al. The average Fe value was 0.31 ± 0.06 mg/g dry weight, dw (0.08 ± 0.02 mg/g wet weight, ww), the highest Fe value was measured in March whereas the lowest Fe value was measured in June, and a statistically

significant difference was found between the months ($p < 0.05$). The average Zn value was 0.11 ± 0.02 mg/g dw (0.03 ± 0.00 mg/g ww), and Zinc did not present clear temporal trends. Mn showed a statistically significant difference especially in March and June ($p < 0.05$). The average value of Al per month was found to be 0.04 ± 0.02 mg/g dw (0.01 ± 0.00 mg/g ww). The average B value was found to be 0.01 mg/g dw only in April and June, whereas 0.02 mg/g dw in the other months, and there was a statistically significant difference between the months ($p < 0.05$). The average Cu value was 0.01 ± 0.00 mg/g dw (1.01 ± 0.36 µg/g ww), and the difference between the months was statistically significant ($p < 0.05$). Selenium (Se) was detected in smooth scallop meat in trace levels (0.01 mg/g dw, 1.18 µg/g ww) only in December, and the differences between the months were significant ($p < 0.05$) (Table 2.)

Of the macro elements, S was generally found to be low in winter and spring, whereas high in summer and autumn. It was observed that Na is usually high in summer and autumn, low in winter and spring, and statistically different between the months ($p < 0.05$). The lowest K value was measured in April, whereas the highest value was measured in October. P values varied in the range of 4.86-7.10 mg/g dw (1.55 ± 0.18 mg/g ww) during the study and the differences between the months were statistically significant ($p < 0.05$). The average value of Mg was 2.34 ± 0.36 mg/g dw (0.56 ± 0.09 mg/g ww) and it varied between 1.64 mg/g dw (0.38 mg/g ww) in April and 2.92 mg/g dw (0.73 mg/g ww) in July and the difference was statistically significant ($p < 0.05$). The average value of Ca was 1.12 ± 0.34 mg/g dw (0.22 ± 0.27 mg/g ww) and it varied between 0.61 mg/g dw (0.15 mg/g ww) in March and 1.90 mg/g dw (0.48 mg/g ww) in July ($p < 0.05$). (Table 2.)

According to the correlation graph of the elements, negatively correlated were found between B and Fe, Se and Mn, Al and Fe, Mn, S and Ca. A positively correlated was observed between other elements (Figure 2).

There were three dimensions with ≥ 1 according to their eigen values. This showed that three dimensions will be sufficient to explain all elements (Table 3.)

According to the graph of the percentage of variances that can be explained, the elements were examined in four dimensions. Among these four dimensions, the first dimension explained 58.7% of the variances, while the second dimension explained 17.92% (Figure 3). Therefore, examining the first and the second dimensions (since it explained 76.62% of the variances) was sufficient for the evaluation of all elements.

Table 2. Monthly variation of element composition in smooth scallop (mg/g dw)¹

Element	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
Microelement												
Fe	0.39 ^{cd}	0.33 ^{abcd}	0.32 ^{abcd}	0.32 ^{abcd}	0.29 ^{abcd}	0.37 ^{bcd}	0.29 ^{abcd}	0.28 ^{abc}	0.20 ^a	0.23 ^{ab}	0.34 ^{abcd}	0.43 ^d
Cu	0.01	0.01	0.01	0.01	0.01	0.01	ND	0.01	0.01	ND	0.01	ND
Mn	0.11 ^g	0.07 ^{def}	0.06 ^{bdef}	0.05 ^{bode}	0.08 ^{efg}	0.05 ^{bode}	0.03 ^{ab}	0.04 ^{bcd}	0.01 ^a	0.03 ^{abc}	0.07 ^{cdef}	0.08 ^{fg}
Zn	0.12	0.09	0.10	0.11	0.13	0.13	0.12	0.11	0.10	0.08	0.12	0.10
Al	0.02 ^{abc}	0.03 ^{bode}	0.04 ^{de}	0.03 ^{cde}	0.03 ^{bcd}	0.05 ^f	0.08 ^g	0.07 ^g	0.04 ^{ef}	0.01 ^a	0.04 ^{cde}	0.02 ^{ab}
Se	ND	ND	ND	ND	ND	0.01	ND	ND	ND	ND	ND	ND
B	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.01
Macroelement												
Na	16.98 ^{de}	15.69 ^{bode}	16.11 ^{bode}	16.31 ^{ode}	15.27 ^{bode}	18.79 ^e	13.12 ^{abcde}	10.97 ^{abc}	10.37 ^{ab}	9.39 ^a	13.70 ^{abode}	12.25 ^{abcd}
Mg	2.92 ^c	2.38 ^{abc}	2.47 ^{abc}	2.47 ^{abc}	2.35 ^{abc}	2.80 ^b	2.56 ^{abc}	2.10 ^{abc}	1.91 ^{ab}	1.64 ^a	2.30 ^{abc}	2.14 ^{abc}
K	13.63	12.17	12.76	14.44	13.08	13.42	11.38	10.48	10.59	8.04	10.61	10.31
Ca	1.90 ^b	1.37 ^{ab}	1.10 ^{ab}	1.33 ^{ab}	1.09 ^a	1.37 ^{ab}	0.96 ^a	1.01 ^a	0.61 ^a	0.72 ^a	1.06 ^a	0.96 ^a
P	6.92	6.40	6.82	6.63	6.51	6.55	6.65	6.23	7.10	4.86	6.93	5.98
S	35.01	28.22	30.85	33.66	30.86	30.67	7.10	6.53	6.30	5.35	6.98	7.25

¹Different superscript letters within rows represent significant differences ($p < 0.05$) based on results of the post hoc Tukey test.

²N.D.: Not detected.

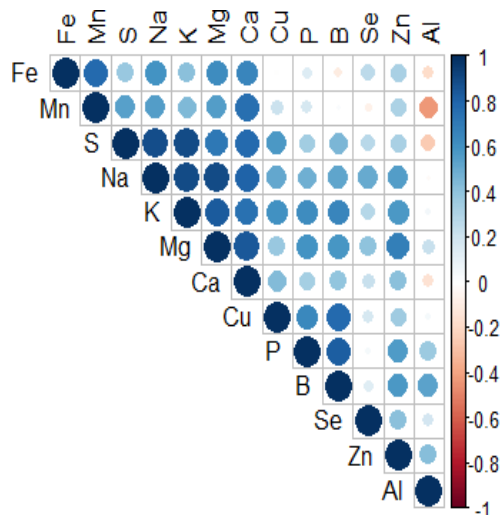


Figure 2. Correlation plot of elements (Fe, Mn, Cu, B, Se, Zn, Al, P, S, Na, K, Mg, and Ca)

Table 3. Eigen value of elements (Fe, Mn, Cu, B, Se, Zn, Al, P, S, Na, K, Mg, and Ca)

	Eigen Value	Variance (%)	Cumulative Variance (%)
Dimension 1	5.81	48.39	48.39
Dimension 2	2.52	21.02	69.41
Dimension 3	1.36	11.35	80.76
Dimension 4	0.96	7.97	88.72
Dimension 5	0.48	4.00	92.73
Dimension 6	0.35	2.89	95.61
Dimension 7	0.30	2.50	98.11
Dimension 8	0.15	1.24	99.35
Dimension 9	0.06	0.51	99.86
Dimension 10	0.01	0.10	99.96
Dimension 11	0.00	0.04	100.00

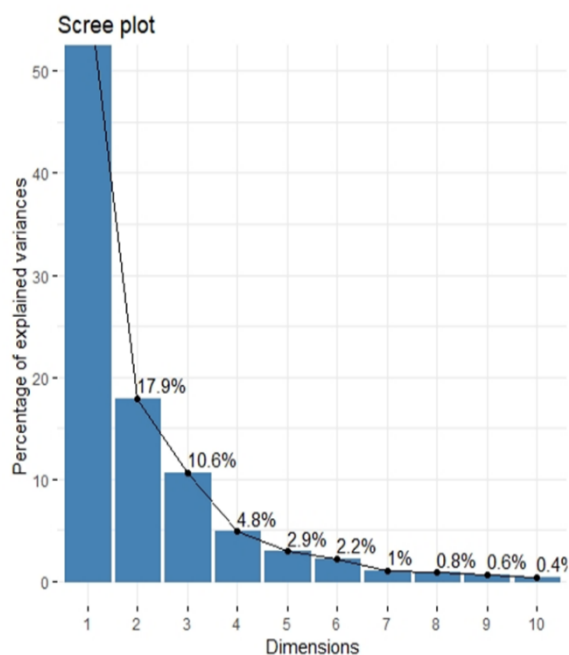


Figure 3. Percentage of explained variances of elements (Fe, Mn, Cu, B, Se, Zn, Al, P, S, Na, K, Mg and Ca)

According to the biplot graph, the contribution of Na, Mg, K, Ca, S, B elements were higher at Dimension 1. Furthermore, Al, Mn, B, and Fe elements among other elements were higher at Dimension 2. There were proximity were observed in May with Al, August with Fe, Mn, October with Se, Zn, Cu, P, December with K, October and November with Ca, S, Na, and Mg (Figure 4).

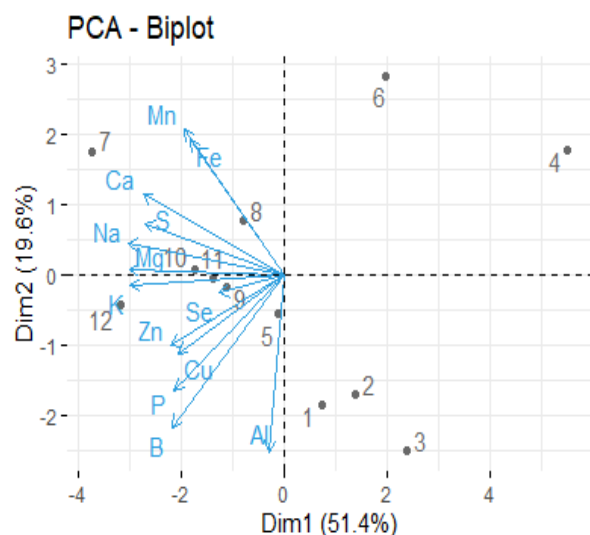


Figure 4. Principal component analysis (PCA)-Biplot of the composition of element values (Fe, Mn, Cu, B, Se, Zn, Al, P, S, Na, K, Mg and Ca, 1: January, 2: February, 3: March, 4: April, 5: May, 6: June, 7: July, 8: August, 9: September, 10: October, 11: November, 12: December).

THQ and HI values were used to determine the non-carcinogenic health risks posed by the elements in the consumption of smooth scallops. The THQ and HI values of the smooth scallop are given in Table 4. THQ and HI values below 1 in all months throughout the year, confirmed that continuous consumption of smooth scallop for 70 years had no adverse effects on human health.

Table 4. Rererence dose (Rfd), Estimated daily intake (EDI), Target hazard quotient (THQ) and Hazard index (HI) values of elements via consumption of smooth scallop

Elements	Rfd (mg/kg bw-day)	EDI of smooth scallop (mg/70kg bw-day)	THQ of smooth scallop
Na	2x10 ³	4.83x10 ⁻⁵	6.17x10 ⁻⁴
Mg	3.5x10 ²	8.01x10 ⁻⁶	5.85x10 ⁻⁴
K	2x10 ³	4.04x10 ⁻⁵	5.16 x10 ⁻⁴
Ca	8 x10 ²	3.87x10 ⁻⁶	1.24 x10 ⁻⁴
P	3 x10 ²	2.22 x10 ⁻⁵	1.89 x10 ⁻³
Fe	7x10 ⁻¹	1.08 x10 ⁻⁶	3.93 x10 ⁻²
Cu	4x10 ⁻²	2.16 x10 ⁻⁸	1.38 x10 ⁻²
Mn	1.4x10 ⁻¹	1.93 x10 ⁻⁷	3.53 x10 ⁻²
Zn	3x10 ⁻¹	3.77 x10 ⁻⁷	3.21 x10 ⁻²
Al	1	1.28 x10 ⁻⁷	3.27 x10 ⁻³
Se	5x10 ⁻³	1.14 x10 ⁻⁸	5.83 x10 ⁻²
B	2x10 ⁻¹	5.9x10 ⁻⁸	7.54 x10 ⁻³
ΣHI			0.19

Rfd value data taken from WHO (2012), FAO/WHO (1993, 2002, 2010), Aksoy (2014), USEPA (2019a).

DISCUSSION

Bivalves taking elements not only from water and food but also from inorganic particles they digest (Warnau et al., 1996; El-Sikaily et al., 2004). However, even though they are in the same region, the element contents in bivalves may differ. Differences in element levels in bivalves depend on the bioaccumulation capacity of each species, physiological conditions (reproductive activity, growth, filtration rate), biotic factors (age, height, and sex), genetic characteristics, abiotic factors (salinity, pH, temperature, and dissolved oxygen) depends on the chemical form of the elements, the structure of the sediment, and the area (O'Connor, 1996; Mendez et al., 2001; Skinner et al., 2004; Fuentes et al., 2009; Ulutarhan et al., 2019).

In humans, Fe has several vital functions including transporting O₂ to tissues via the red blood cells hemoglobins, being a transport medium for electrons in cells, and being a part of important enzyme systems in various tissues (FAO/WHO, 2002). Fe is found in pigments (hemoglobin) that are found in the blood of many vertebrate and invertebrate organisms and carry oxygen and carbon dioxide for cell respiration (Clark, 1992). The increase in Fe concentrations are an indicator of the field's nutrient flow (drawdown),

phytoplankton biomass, productivity (Fitzwater *et al.*, 2000). Fe deficiency is seen in more than two million people around the world (Stoltzfus and Dreyfuss, 1998). Different consumption values are recommended for Fe based on the criteria including age, gender, etc. There is 300 mg Fe stored in the body, and 1 mg/day Fe in men, and 1.5 mg/day in women are excreted from the body (Aksoy, 2014). It is recommended to take 10 mg Fe for adult men and 15 mg/day for women. Fe intake is recommended as 15 mg/day (Aksoy, 2014) during pregnancy and breastfeeding, 11 mg/day for 0.5-1 year-olds (Schümann *et al.*, 2007), 10 mg/day for babies and children from 6 months to 3 years (Aksoy, 2014). In the present study, the Fe values in smooth scallop were lower than those reported in the previous studies (Orban *et al.*, 2007; Periyasamy *et al.*, 2014).

Cu plays an important role in the functioning of various enzymes (Bajgas, 2000; Hambidge, 2000), carbohydrate metabolism, photosynthesis (Bajgas, 2000). It is also essential for the circulatory system (Walker *et al.*, 2002). So it has to be consumed by humans, fish, bivalves, and other aquatic creatures (FAO/WHO, 2004). Excessive Cu has a toxic effect on the body and prevents the functions of some enzymes (Bajgas, 2000). FAO/WHO (2004) and USEPA (2019) temporarily determined the edible daily intake (EDI) as 0.4 mg/kg/day. The Cu value found in the present study was below the limits determined by FAO/WHO (2004). It was thought that consuming 42.85 g smooth scallop daily will meet the amount recommended by FAO/WHO (2004) and USEPA (2019). Also, the Cu levels decrease when industrial and urban emissions, fertilizers, algicides, fungicides, molluscicides, cyanobacteria in the region decrease (Moffett *et al.*, 1997; Besada *et al.*, 2002; Cheriyan *et al.*, 2015). Cu is found in the greenish-blue pigment (hemocyanin) that carries oxygen of mollusks and crustaceans (Clark, 1992). The amount of influx and efflux of Cu element in bivalves vary among species (Cai and Wang, 2019).

The dissolved concentration of Zn in seawater ranges around <0.1 nmol/kg in surface waters. Zn plays a role in the synthesis of some enzymes that affect CO₂ and P uptake, photosynthesis, phytoplankton growth and microalgal growth, and the catabolism of carbohydrate, fat, protein, and nucleic acids (Morel *et al.*, 1994; Bajgas, 2000; FAO/WHO, 2002; Shaked *et al.*, 2006; Shariati and Yahyaabadi, 2006). In the present study, the Zn value was found to be lower than those in *P. maximus* (12.6-16.9 mg/kg wet meat) (Manthey-Karl *et al.*, 2015), *D. incarnatus* (0.34 mg/g dry meat) (Periyasamy *et al.*, 2014), and *C. gallina* (0.91-1.48 mg/100g wet meat) (Orban *et al.*, 2007). Since Zn is an essential element observed in the cell wall of bacteria and diatoms, the death or decay of these microorganisms increases the amount of this element in the upwelling zone where coastal water and seawater are mixed (Lewis and Luther III, 2000; Monteiro and Roychoudhury, 2005; Baines *et al.*, 2016; Grasse *et al.*, 2016). In the present study, Zn values of smooth scallop were found to be safe for human consumption. Based on

FAO/WHO (2004), it can be thought that consuming at max 350 g per week (7 g per day) would be sufficient.

The daily Al consumption should be 4-9 mg (Hellström-Westas and Rosen, 2006). The tolerable daily intake has been reported as 1 mg/kg body weight (WHO, 1996; USEPA, 2019). Examining the values found in the present study, consuming 50 g per week (7 g per day) of the smooth scallop collected from the Çardak Lagoon is within the limits determined by EFSA (2013).

Se is an essential micronutrient with selenoproteins that perform various metabolic functions in animals and humans (Wen and Hu, 2010; Rayman, 2020). Many of the selenoproteins affect antioxidant metabolism (Steinbrenner *et al.*, 2016). Se plays a role in protection from infections, promotes growth and development (FAO/WHO, 2002). Thyroid dysfunction may occur in Se deficiency. The Se concentration in the blood should be 60-100 µg. Chronic high consumption of Se can cause changes in nail morphology, hair loss, diarrhea, central nervous system disorders, anorexia, kidney and liver damage (Selinus *et al.*, 2005). The Se values in sediments and living things in the world vary due to different environmental conditions and agricultural practices (FAO/WHO, 2002). A daily intake of 55-75 µg Se is recommended (Aksoy, 2014). In the present study, Se was detected in trace levels in smooth scallop meat only in December and below the detection limit in other months. Therefore, it can be argued that consuming 5.5-7.5 g of smooth scallops per day from the Çardak Lagoon during December will meet the daily requirement.

Turkey ranks first in the world in the B source (Yiğitbaşıoğlu, 2004). B can be obtained from both foods and water. Evaluating the B element together with Ca, P, and Mg elements, contributes to the protection of vitamin D in the body (sufficient quantity of boron prevents vitamin D deficiency and, hence, osteoporosis and weakening and breaking of the bones) (Yakıncı and Kök, 2016). The B element is also effective in preventing the loss of Ca element in the body and in the transport of Ca element between cells (Aksoy, 2014). In the present study, a positively correlated was found between Ca and B ($p < 0.05$). For adults, a daily intake of 0.4-0.5 mg/kg body weight B is recommended (CODEX, 2007). In line with the results obtained from the present study, it can be argued that the smooth scallop in the lagoon contains B elements throughout the year, and consuming 40 g smooth scallop per day will be sufficient to meet the B requirement.

Although the presence of 77 elements in seawater was detected, only 7-8 of them were abundant. In order of abundance, these elements are Cl, Na, Mg, S, Ca, K, Br, and C (Bat *et al.*, 1998). In the present study, it was observed that the elements contained in the flesh of the smooth scallop were in a similar order except for sulfur. The anoxic nature of

sedimentary affects the amount of sulfur in the water column (Büyükaş, 2017). In the present study, it can be argued that the high values of sulfur in the spring and summer months when the temperature increased was associated with the fact that the sediment was anoxic and, as a result, the water column was affected by this situation. In other words, the water properties of the environment may have affected the sulfur content of the smooth scallop.

In the present study, the Mg values in smooth scallop were much lower than those in *P. maximus* (330-356 mg/kg ww) (Manthey-Karl et al., 2015), *C. gallina* (74.3-89.4 mg/100g ww) (Orban et al., 2007), and *D. incarnatus* (60.54 mg/g dw) (Periyasamy et al., 2014). Mg is found in shell formation in small amounts as Mg-calcite (Broadaway, 2012). In the present study, it can be argued that the Mg in the smooth scallop will decrease due to its contribution to the shell growth in the spring. Evaluating in terms of nutrition, the daily recommended consumption is 350 mg for men and 280 mg for women (Aksoy, 2014). It can be argued that it would be sufficient to consume 500-628 g smooth scallop per day purchased from the Çardak Lagoon to meet this amount.

As a result of the death of organisms, a significant part of organic P dissolved or in particulate form in seawater turns into inorganic phosphate with the effect of phytoplankton species, the remaining part turns into inorganic phosphate by bacteria and this inorganic P turns into organic matter that phytoplankton and other marine creatures can benefit from (Karl et al., 1995; Geldiay and Kocataş, 1988; ÇŞB, 2020). Although P in seawater is maximum in summer, it was observed to decrease in autumn and reach a minimum level in the winter months. However, it was concluded that these changes depend on the regions (Geldiay and Kocataş, 1988). In the present study, although the P value in smooth scallop was stable, it was generally the lowest in spring whereas highest in autumn. Also, the results obtained in the present study were similar to those reported by Orban et al. (2007) for *C. gallina* (108-177 mg/100g wet meat). The recommended daily P consumption is 300-500 mg (Aksoy, 2014). Therefore, it can be argued that consuming 300-500 g smooth scallop per day in the present study will meet the P requirement.

Ca is of importance since it provides rigidity to the skeleton and plays an important role in many metabolic processes (FAO/WHO, 2002). Smooth scallop's shell consists of CaCO₃. In the present study, one of the reasons for the decrease in this element in spring may be the contribution of Ca to the shell formation. Ca value determined in smooth scallop in the present study was lower than those reported in previous studies (Orban et al., 2007; Manthey-Karl et al., 2015). In terms of human consumption, the daily requirement is recommended as 800 mg, and this value increases to 1200 mg for pregnant and breastfeeding women (Aksoy, 2014). In general, it can be recommended to consume daily 2 kg of smooth scallop in the Çardak Lagoon. In previous studies, it was stated that the macro element with the highest value in smooth scallop meat is usually the K element (Bilandzic et al.,

2015; Manthey-Karl et al., 2015). The values found in this study were lower than the values found for *P. maximus* (3860-4118 mg/kg wet meat) (Manthey-Karl et al., 2015), *C. gallina* (221-257 mg/100g wet meat) (Orban et al., 2007), *D. incarnatus* (20.36 mg/g dry meat) (Periyasamy et al., 2014). The daily recommended K consumption for a healthy nervous system and a steady heart rhythm is 2000 mg (Aksoy, 2014). In this study, it can be recommended to consume 167 g of smooth scallop per day to meet the amount needed. The Na values obtained in the present study were higher than those reported in the previous studies (Orban et al., 2007; Manthey-Karl et al., 2015), however, the values exhibited a similar pattern of change during the year (Orban et al., 2007). The recommended daily minimum Na consumption is 500 mg (Aksoy, 2014) and the maximum recommended value is 2 g (WHO, 2012). According to the Na values in this study, it was thought that consuming 167 g of smooth scallop meat per day, especially in autumn and summer, will meet the daily Na amount required. Mn is one of the vital microelements. It is also a structural component of some enzymes (Wen and Hu, 2010). Considering the Mn values determined in the present study, the consumption of 13-33 g smooth scallop is within the limits determined by CODEX (2007).

CONCLUSION

The results obtained in the present study provide valuable information for both smooth scallop breeders and the consumers. For smooth scallop consumers, the data obtained from the present study can be a guide for the months, and consumption amounts for the smooth scallop in this region. Since the smooth scallop in Çardak Lagoon meets the criteria set by the Ministry of Agriculture and Forestry in terms of element composition, its cultivation is recommended in this region.

It was observed that *F. glaber* individuals collected from Çardak Lagoon were suitable for consumption in terms of their element content. Also, in the present study, the heavy metal content of smooth scallop meat was below the limit values specified by organizations such as the Turkish Food Codex, WHO, FAO, etc. In addition, the fact that the THQ and HI values of the smooth scallop were below 1 in all months throughout the year confirmed that their consumption did not have a negative effect on human health.

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