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RESEARCH ARTICLE

Seasonal Variations in Proximate and Mineral Compositions of *Holothuria* (*Roweothuria*) *poli* (Delle Chiaje, 1823) Distributed Along the Coasts of Çanakkale, Türkiye

İbrahim Ender Künili[1]*, Fatma Çolakoğlu[2]

[1]Department of Fisheries and Fish Processing Technology, Faculty of Marine Science and Technology, Çanakkale Onsekiz Mart University, Çanakkale, Türkiye https://orcid.org/0000-0003-2830-6979
[2]Çanakkale Onsekiz Mart University, Faculty of Applied Sciences, Food Technology, 17100, Çanakkale, Türkiye https://orcid.org/0000-0002-2211-8371

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Abstract: Sea cucumbers are soft-bodied echinoderms and some species are highly economic thanks to their unique biochemical compositions. *Holothuria (Roweothuria) poli* is an economically important species in Turkey and has been extensively exploited in the Mediterranean to meet the international market demand in the last decade. In this study, meat yield, proximate and mineral compositions of *H. poli* from the coasts of Çanakkale,Turkey, were investigated to determine the effect of seasons on food product quality and safety. The lowest meat yield was determined in the autumn samples, whereas the highest levels were in the samples from the spring to summer. The percent levels of moisture, protein, fat, ash, and carbohydrate levels were in the range of 80.8 - 84.0, 7.6 - 10.1, 1.4 - 1.8, 6.2 - 7.1, and 0.2 - 0.8, respectively. The levels of minerals were found in declining order; Na >Ca>Mg> K >S> P>Si> B> Mn> Zn> Fe> Cu> Hg> Pb> Sn> Se> Cr> As> Co> Sb> Ni> Cd> Pt. Apart from macro minerals, Si and B were determined as the most abundant minerals. The important minerals in human nutrition were found to be at desirable levels, whereas toxic minerals were found under the threshold levels. Our findings indicated significant seasonal differences in meat yield, proximate and mineral compositions of *H. poli,* but more importantly, this species tends to accumulate some minerals regardless of seasons. Further studies to better understand the optimal utilization season by determining the mineral accumulation tendency and product quality will be valuable for future research.

Anahtar kelimeler:

Holothuria poli
Element
Mineral
Toksik metal
Besin kompozisyonu

Çanakkale Kıyılarında Dağılım Gösteren *Holothuria* (Roweothuria) *poli* (Delle Chiaje, 1823)'nin Besin ve Mineral Kompozisyonlarındaki Mevsimsel Değişimler

Öz: Deniz hıyarları, benzersiz biyokimyasal bileşimleri sayesinde bazıları oldukça ekonomik olan yumuşak gövdeli derisidikenlilerdir. *Holothuria (Roweothuria) poli* Türkiye'deki ekonomik deniz hıyarı türlerinden biri olup son on yılda uluslararası pazar talebini karşılamak için Akdeniz'de yoğun bir şekilde avlanmıştır. Bu çalışmada, mevsimlerin gıda ürün kalitesi ve güvenliğine etkisini belirlemek için Türkiye'nin Çanakkale kıyılarında bulunan *H. poli*'nin et verimi, besin ve mineral bileşimleri araştırılmıştır.Elde edilen sonuçlara göre en düşük et verimi sonbahar örneklerinde belirlenirken, en yüksek seviyeler ilkbahardan yaza kadar olan örneklerde tespit edilmiştir. Nem, protein, yağ, kül ve karbonhidrat seviyeleri yüzdesel olarak sırasıyla, 80,8 – 84,0; 7,6 – 10,1; 1,4 – 1,8; 6,2 – 7,1 ve 0,2 – 0,8 aralıklarında belirlenmiştir. Mineral seviyeleri azalan sıra ile; Na >Ca>Mg> K >S> P Si> B> Mn> Zn> Fe> Cu> Hg> Pb> Sn> Se> Cr> As> Co> Sb> Ni> Cd> Pt şeklinde bulunmuştur. Makro mineraller dışında Si ve B en bol mineraller olarak belirlenmiştir. İnsan beslenmesindeki önemli bazı mineraller arzu edilen seviyelerde bulunurken, toksik mineraller otoriteler tarafından bildirilen eşik seviyelerin altında bulunmuştur. Bulgularımız, *H. poli*'nin et verimini, makro besin maddelerini ve mineral bileşimleri üzerinde önemli mevsimsel farklılıklar olduğunu, ancak daha da önemlisi, bu tür mevsimlere bakılmaksızın bazı mineralleri biriktirme eğiliminde olabileceğini göstermiştir. Mineral birikim eğiliminin ve ürün kalitesinin belirlenmesi açısından optimal kullanım mevsiminin daha iyi anlaşılmasına yönelik çalışmalar, gelecekte yapılacak araştırmalar için önemlidir.

*Corresponding author: enderkunili@yahoo.com

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Introduction

Sea cucumbers are important marine animals belonging to the Holothuroidea class in Echinodermata phylum. They are a group of worm-like and soft-bodied organisms and can be found in nearly all seas. Sea cucumbers belonging to Holothuroidea class are represented approximately by 1773 species, and 66 of them are known to be economically important (Purcell, 2010; WoRMS, 2022). Economic value of sea cucumbers are shaped by the demand on their processing quality and sensory profiles such as size, colour, and texture along with by their biochemical composition and potential pharmacological utilization (Künili and Çolakoğlu, 2018; Künili and Çolakoğlu, 2019). In the Mediterranean, one of the economic sea cucumber species is known to be *Holothuria (Roweothuria) poli*, which has been under a heavy exploitation during the last decade to meet the international market demand (Künili and Çolakoğlu, 2019; Künili, 2022).Extensive populations can be observed in shallow water habitats such as sandy, muddy and rocky seabeds as well as among sea grass. In Turkey, this species forms dense populations from the Aegean Sea to the Marmara Sea. Fishery production involves collection by SCUBA diving. Catching of this species has recently been banned in coastal areas of Turkey. Once harvested sea cucumbers are directly dissected free from their viscera on board and the remaining body walls are transported to processing plants where they are processed as frozen products and beche-de-mer, which is a unique processing method for sea cucumbers including boiling, salting and drying steps (Çaklı et al., 2004; Künili and Çolakoğlu, 2019). The demand for this species varies by seasons, due to changes in product quality which is affected by sensorial acceptances, biochemical composition, nutritional properties as well as meat yield. There are numerous studies in the literature that report the nutritional quality and biochemical properties of Holothurians in the Mediterranean. However, the effect of seasons on the proximate and detailed mineral compositions of *Holothuria poli* from the Northern Aegean Sea to the southern Marmara Sea still needs to be investigated for optimal utilization in the future. Therefore, in this study, changes in macro nutritional and mineral composition levels of *H. poli* were investigated. Findings from this study may provide valuable insight for future utilization of this species.

Material and Methods

Holothuria (Roweothuria) poli (Figure 1) specimens were hand collected by SCUBA diving from 1-15 m depths in Dardanos (40°4’26”N; 26°21’16”E) and Yapildak regions (40°12’26”N; 26°28’36”E) located at Çanakkale Strait (Figure 1). A total of 100 specimens, 25 for each season, were collected between March 2018 and July 2020. Live specimens were individually packed after their first total weights were recorded and then transported to the laboratory via an ice-cooled insulated box in 4 hours. In the laboratory, morphometric measurements were taken and specimens were then prepared for analysis.

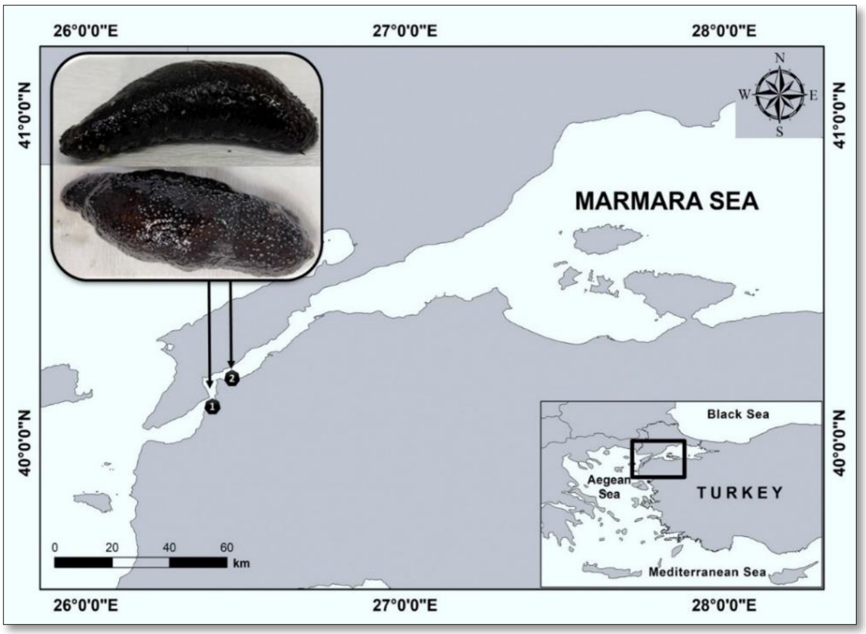

Figure 1. *Holothuria* (*Roweothuria*) *poli* and sampling locations; 1- Dardanos and 2- Yapildak

Analysis

Sample preparations

Morphometric measurements were performed according to the methods described by Dereli et al. (2016) and Künili (2022). The total length, total weight (TW) and body wall weights (BW) were measured using a tape measure and a two-digit precision scale. Once measurements completed, viscera and ceolomic fluids of sea cucumber specimens were removed by dissecting via a sharp knife. Remaining body wall tissues were cut into small pieces and used for all analysis after the homogenization process.

Meat yield and proximate composition

Meat yield (MY) of specimens was calculated using total weight (TW) and body wall weight (BW) according to following equation;

MY(%) = [(BW/TW)x100]

The water content was determined from approximately 5 g of minced body wall by oven drying at 105 ± 3°C until a constant weight (AOAC, 2000). Percent protein (Kjeldahl N×6.25) was determined by the method of AOAC (2000). Extraction of lipids from samples was carried out with a mixture of chloroform, methanol, and water (Bligh and Dyer, 1959). Ash was determined in an oven at 550±5°C for 24 h (AOAC, 2000). Total carbohydrate level was calculated by the method of FAO (2003).

Mineral composition

Mineral composition of samples was determined with the method described by EPA (1998, 2000). Briefly, 0.2 g homogenized samples were mixed with 4 mL of nitric acid (65% w/v) and placed in flasks. Then, the flasks were subjected to acidic digestion in microwave oven (CEM Mars Xpress) for 15 min. Solubilized samples were filtered via Whatman No. 2 filter paper and diluted with deionized water. For determination of the amount of minerals in diluted samples, ICP-MS (Agilent 7700, Agilent Technologies, Santa Clara, CA, USA) and ICP-OES (PerkinElmer, Inc. Shelton, CT, USA) devices were used. An internal stock solution of germanium (Ge), indium (In), lutetium (Lu), rhodium (Rh), scandium (Sc), and terbium (Tb) (0.250 µg/l) was used in analyzes, and gold (Au) was used to stabilize the Hg and minimize memory effects in the tubing and during nebulization. Certified reference material, ERM$^{®}$-CE278k mussel tissue (European Joint Research Center, JRC, Geel, Belgium) was used to determine recoveries and to test accuracy of the analyzes. For the certified reference material, limit of detection (LOD) and limit of quantification (LOQ) values (mg/kg) along with recovery rates (%) of trace elements were as follows; 0.010-0.050 for Hg (103%); 0.005-0.010 for Cd (99%), 0.005-0.010 for Pb (101%), 0.005-0.010 As (104%), 0.025-0.075 for Ni (103%), 0.004-0.010 for Cr (96%), 0.005-0.010 for Co (94%), 0.010-0.025 for Cu (102%), 0.055-0.125 for Zn (98%), 0.015-0.045 for Se (102%), 0.005-0.017 for Fe (97%), 0.035-0.120 for Mn (96%). For the other minerals, only LOD values were expressed in their related columns when they were out of detection limit (Table 2).

All analyzes were performed in triplicate and the results of mineral levels were given as mg/kg wet weight basis.

Statistical analysis

The data were subjected to one-way analysis of variance (ANOVA) with Tukey's multiple comparison tests. The suitability of data for ANOVA was tested using Anderson–Darling Test for normality and Levene's Test for equal variances (homogeneity). The software used was Minitab 17 (Minitab, LLC, USA). All experiments were carried out in triplicate and the data calculated as average ± standard deviation. The significance of differences was defined at $p < 0.05$.

Results and Discussion

The mean total length and total weight of *H. poli* samples were 14.88±1.22 cm and 55.67±7.42 g, respectively. The mean weight of body wall (gutted weight) for all seasons was determined as 39.62±8.25 g. Mean meat yields and proximate compositions of *H. poli* according to seasons are summarized in Table 1.

The mean meat yields of *H. poli* samples in all seasons were in the range of 47.37% and 66.90%. The mean contents of water, protein, ash, lipid, and carbohydrate in the samples ranged between 81.25%-83.69%, 7.80%-9.84%, 6.46%-6.85%, 1.35%-1.71%, and 0.36%-0.67%, respectively. The meat yield of spring and autumn samples differed significantly in winter and summer samples ($P<0.05$). Mean protein amounts in the spring (8.34%) and summer (9.84%) samples were found to be higher than those found in the autumn and winter seasons ($P<0.05$). Ash contents of samples were significantly different in all seasons ($P<0.05$) but the winter samples showed similarity to those collected in the spring and summer seasons ($P>0.05$). Lipid content was lowest in autumn and winter seasons and differed significantly from the spring and summer samples ($P<0.05$). Carbohydrate levels in the autumn and spring samples showed similarity and differed significantly from samples of the winter and summer seasons ($P<0.05$).

Table 1. Seasonal changes in meat yield and proximate composition of *Holothuria poli* (percentage of wet weight)*

Seasons	Meat Yield	Water	Protein	Ash	Lipid	Carbohydrate
Autumn						
Min-Max	24.31-84.94	83.48-83.97	7.59-7.93	6.17-6.59	1.29-1.42	0.51-0.92
Mean ± Std	47.37±11.70^{a}	83.69±0.17^{a}	7.81±0.12^{a}	6.46±0.15^{a}	1.35±0.04^{a}	0.67±0.17^{a}
Winter						
Min-Max	45.99-76.72	83.28-83.96	7.64-7.92	6.61-6.81	1.33-1.48	0.24-0.88
Mean ± Std	59.22±7.52^{b}	83.60±0.26^{a}	7.80±0.10^{a}	6.70±0.07^{bc}	1.40±0.06^{a}	0.49±0.22^{b}
Spring						
Min-Max	60.15-76.96	82.41-82.66 *	8.04-8.66	6.58-6.76	1.63-1.72	0.23-0.83
Mean ± Std	66.90±5.44^{c}	82.69±0.40^{ab}	8.34±0.22^{b}	6.64±0.07^{b}	1.68±0.03^{b}	0.65±0.21^{a}
Summer						
Min-Max	52.01-74.66	80.81-81.76	9.73-10.02	6.61-7.01	1.56-1.80	0.11-0.68
Mean ± Std	60.84±7.27^{b}	81.25±0.35^{b}	9.84±0.12^{c}	6.85±0.18^{c}	1.71±0.10^{b}	0.36±0.24^{c}

* *: Data represent mean of triplicated analyses ± SD (n = 3). Different superscript letters (a, b, c) in the same column represent statistical differences among seasons ($p < 0.05$).

The water content was similar to those reported for other sea cucumber species, including *H. tubulosa*, *H. poli*, *H. mammata* (Çaklı et al., 2004; Aydın et al., 2011; Künili and Çolakoğlu, 2019; Künili, 2022), *H. arguinensis* (Roggatz et al., 2016), *Actinopyga mauritiana*, *H. scabra*, *Bohadschia marmorata*, and *H. leucospilota* (Omran, 2013). However, moisture values were also reported lower than our results in several sea cucumber species, such as *H. arenicola*, *Actinopyga mauritiana* (Haider et al., 2015), *Paracaudina australis* (Widianingsih et al., 2016), and *Apostichopus japonicus* (Lee et al., 2012). Protein content ranged from 7.75% to 10.22%, and these results were similar to those reported other studies (Çaklı et al., 2004; Aydın et al., 2011; Haider et al., 2015; Roggatz et al., 2016; Künili and Çolakoğlu, 2019; Künili, 2022). With respect to the lipid content of the sea cucumber, our results were higher than those of reported values by Aydın et al. (2011), Roggatz et al. (2016), Widianingsih et al. (2016), and Roggatz et al. (2018). Our results have shown slight differences in dry weight percentage of protein and ash and lipid content of *Holothuria tubulosa* compared to those reported from the same region by Türk Çulha et al. (2017) and *H. poli* from Southern Adriatic Sea by Sicuro et al. (2012).

Holothurians contain organic and inorganic nutrients, which are important parts of nutritional composition. These nutrients, which depend on species, season, habitat, and probably the life span, make holothurians valuable food products (Khotimchenko, 2015). In this study, protein and fat content in the spring and summer season significantly differed from those in other seasons (P<0.05), while ash and carbohydrate levels mainly differed in the summer season (P<0.05). Increased feeding activity due to higher water temperatures were reported in late spring and summer seasons before reproduction for *Holothuria tubulosa* which coexist with *H. poli* in the region (Dereli et al., 2016; Künili and Çolakoğlu, 2019). This could also be valid for *H. poli* as higher feeding activity and growth occur at 25°C for the Mediterranean holothurians (Coulon and Jangoux, 1993; Günay et al., 2015). Moreover, it was reported that growth, body weight gain and gonadosomatic index of *H. tubulosa* peaked in mid-summer in the Aegean Sea (Kazanidis et al., 2010). Summer months on the coasts of Çanakkale are characterized by increased organic loads due, mainly to, rising anthropological activities and enhanced primary production (Turkoglu, 2010; Künili and Ateş, 2021). This may result in a higher rate of food availability for *H. tubulosa* as well as *H. poli* since both of the species coexist in the same habitat. On the other hand, in the autumn season, the meat yield was found significantly lower than those in other seasons. This could also be related to the reduction in body mass following spawning which mostly occurs in the late spring and summer seasons. Mineral compositions of *H. poli* according to seasons are summarized in Table 2.

Table 2. Seasonal changes in mineral composition of *Holothuria poli* (mg/kg wet weight)*

Element	Symbol	Autumn	Winter	Spring	Summer
Silver	*Ag*	<0.007 (LOD)	<0.007 (LOD)	<0.007 (LOD)	<0.007 (LOD)
Aluminum	*Al*	<0.001 (LOD)	<0.001 (LOD)	<0.001 (LOD)	<0.001 (LOD)
Arsenic	*As*	0.243±0.025^{a}	0.313±0.068^{ab}	0.346±0.047^{b}	0.232±0.043^{a}
Boron	*B*	6.740±0.457^{a}	5.953±0.140^{b}	5.812±0.236^{b}	6.973±0.217^{a}
Bismuth	*Bi*	<0.010 (LOD)	<0.010 (LOD)	<0.010 (LOD)	<0.010 (LOD)
Cadmium	*Cd*	0.030±0.012^{ab}	0.054±0.008^{a}	0.038±0.010^{ab}	0.026±0.009^{b}
Cobalt	*Co*	0.076±0.003^{a}	0.089±0.004^{b}	0.078±0.004^{a}	0.076±0.006^{a}
Chromium	*Cr*	0.287±0.037^{a}	0.368±0.015^{b}	0.312±0.026^{a}	0.294±0.024^{a}
Copper	*Cu*	1.798±0.234^{a}	1.126±0.432^{b}	1.451±0.133^{ab}	1.846±0.122^{a}
Iron	*Fe*	3.332±0.313^{a}	3.620±0.247^{b}	3.802±0.219^{a}	3.169±0.493^{a}
Manganese	*Mn*	3.981±0.193^{a}	5.066±0.136^{b}	4.382±0.114^{ab}	3.865±0.205^{a}
Molybdenum	*Mo*	<0.008 (LOD)	<0.008 (LOD)	<0.008 (LOD)	<0.008 (LOD)
Nickel	*Ni*	0.061±0.006^{a}	0.072±0.008^{bc}	0.066±0.007^{ab}	0.074±0.007^{c}
Lead	*Pb*	0.349±0.023^{a}	0.538±0.036^{b}	0.315±0.030^{ac}	0.252±0.019^{c}
Platinum	*Pt*	0.012±0.002^{a}	0.025±0.011^{b}	0.008±0.006^{ac}	0.006±0.006^{c}
Antimony	*Sb*	0.114±0.040^{a}	0.030±0.012^{b}	0.058±0.026^{c}	0.107±0.024^{a}
Selenium	*Se*	0.625±0.016^{ab}	0.329±0.048^{c}	0.701±0.048^{a}	0.589±0.028^{c}
Silicon	*Si*	8.803±0.322^{a}	8.926±0.012^{ab}	9.120±0.167^{b}	8.527±0.153^{c}
Tin	*Sn*	0.667±0.123^{a}	0.439±0.061^{c}	0.702±0.092^{b}	0.683±0.085^{ab}
Titanium	*Ti*	<0.001 (LOD)	<0.001 (LOD)	<0.001 (LOD)	<0.001 (LOD)
Tungsten	*W*	<0.010 (LOD)	<0.010 (LOD)	<0.010 (LOD)	<0.010 (LOD)
Zinc	*Zn*	3.969±0.395^{a}	4.738±0.209^{b}	4.205±0.302^{ab}	3.846±0.278^{a}
Mercury	*Hg*	0.437±0.104^{a}	0.216±0.004^{b}	0.395±0.054^{ab}	0.430±0.050^{a}
Sulfur	*S*	887.69±16.47^{ab}	637.48±9.40^{c}	745.45±12.94^{b}	867.63±11.90^{a}
Phosphorus	*P*	108.71±5.64^{a}	116.53±11.45^{b}	112.50±8.55^{ab}	103.28±7.86^{c}
Sodium	*Na*	5147.88±93.79^{ac}	6940.74±69.67^{b}	5405.63±81.73^{c}	4829.01±75.19^{a}
Magnesium	*Mg*	1309.05±27.16^{ac}	1419.12±6.37^{b}	1364.50±16.77^{a}	1251.30±15.43^{c}
Potassium	*K*	899.22±43.89^{a}	964.23±15.20^{b}	875.45±24.55^{ac}	867.42±22.58^{c}
Calcium	*Ca*	1934.71±54.34^{ac}	1508.30±29.79^{b}	2082.14±42.06^{a}	1835.47±38.70^{c}

*: Data represent the mean of triplicated analyses ± SD (n = 3). Different superscript letters (a, b, c) in the same row represent statistical differences among seasons ($p < 0.05$).

In all seasons, silver (Ag), Aluminum (Al), Bismuth (Bi), and Molybdenum (Mo) in the samples were lower than the limit of detection (LOD). In all seasons, mean macro minerals levels found in the samples declined in the order; Na >Ca>Mg> K >S> P, whereas trace minerals were found in the declining order Si>B> Mn> Zn> Fe> Cu> Hg> Pb> Sn> Se> Cr> As> Co> Sb> Ni> Cd> Pt.

After macro minerals, the most abundant minerals for all seasons were Si, B, and Mn. Si is the most abundant mineral after oxygen in the earth and used widely for industrial purposes such as, construction materials, ceramics, alloys, electricity, electronic, biological processes, and pharmacology. It is found naturally in water, plant and animals sources and the human body (Araújo et al., 2016). Furthermore, silicon may be involved in the optimal collagen synthesis by activating the hydroxylation enzymes which improves strength and elasticity of collagenous tissues (Reffitt et al., 2003; Araújo et al., 2016). Sea cucumbers are collagen rich animals and their body walls are consisted of collagens up to 70 percent (Saito et al., 2002; Künili, 2017; Künili, 2022). Therefore, Si could be abundant in *H. poli* samples due to its natural abundance and its bioaccumulation tendency for utilization in collagen. This is further supported by the finding of Zaksas et al. (2002) who reported that the Si level in body wall stable protein complex (180 mg/kg) is 120 times higher than the concentration in seawater (1.5 mg/kg) and 2.9 times higher than the whole body (63 mg/kg) of *Eupentacta fraudatrix* (Zaksas et al., 2022).

Boron (B) can also play important roles in physiological activities, such as wound healing actions and expression of extracellular-matrix proteins including tissue-associated proteins and collagen (Benderdour et al., 2000; Hakki et al., 2010; Pizzorno, 2015; Khaliq et al., 2018). Both these physiological properties of B can also be seen in the sea cucumbers. This may be related to the higher occurrence of B, which follows macro minerals and Si levels, in collagen-rich body wall of *H. poli.* Zaksas et al. (2022) reported that the B level in E. *fraudatrix* was 12.2 times higher than that in seawater and the whole body contained 63 mg/kg B (dry weight) which was similar to our findings, considering the water content of *H. poli* can be up to 83.6%.

Mn, Zn, and Fe are known to be essential minerals in the body and other animals for maintaining physiological activities such as skin regeneration, formation of immunity cells, synthesis of proteins, nucleic acids, connective tissue development, and various essential therapeutic enzymes such as metalloproteinases and super oxide dismutase (Thomas, 1970; Agget, 1985; Boccio et al., 2003; Frassinetti et al., 2006). These trace minerals were abundant (Mn: 3.87- 5.07 mg/kg, Zn: 3.85-4.21 mg/kg, Fe: 3.17-3.81 mg/kg) in *H. poli* body wall after Si and B. In general, as mentioned above, one of the common properties of these minerals is that they are components of various enzymes which are mainly related to defensive systems and protein functions. This may also explain the elevated presence of these minerals in the *H. poli* body wall, which is constituted by a defensive and structural protein-rich body wall complex.

In this study, mineral levels in the samples of the summer and autumn seasons showed similarities, and in general, the differences in the levels of all minerals in these seasons, except for Ni, Pb, Pt, Si, Sn, and P, were insignificant (P>0.05). Mineral levels in the samples of the winter season significantly differed from the others, however, some vital minerals and toxic ones, such as Si, B, Zn, P, As, Cd, Cu, and Hg did not differ significantly (P>0.05). The most significant changes among seasons were observed for Ni, P, Pb, Pt, S Sb, Si, and other macro mineral levels (P<0.05).

In this study, in terms of wet weight, results for mineral levels in *H. poli* showed similarities with those reported for the wet weight of *H. tubulosa* sampled from the same region (Künili et al. 2016). The results were also found at lower (Ni, Fe, and Pb) or similar (Cd, Cu, and Zn) levels to those reported for dry weight of *H. tubulosa* by Türk Çulha et al. (2016). In this study, the results also showed similarities with macro mineral levels, except for Ca (145 g/kg), and slight differences in trace mineral levels for *H. poli* from Spain (González-Wangüemert et al., 2018). Moreover, the mean levels of trace minerals in this study were also found lower (Fe), similar (Cr, As, Co, Ni, and Cd,) or slightly higher (Mn, Zn, Cu, and Pb) than those reported by Aydın et al. (2017) for *Holothurians* (*H. tubulosa, H. poli,* and *H. mammata*) from Izmir (Turkey). On the other hand, our results were found to be similar or slightly lower (except As) than those reported for *H. poli* from the Adriatic Sea (Sicuro et al., 2012). In this study, all analyses were performed on a wet weight basis and these reported levels were determined by the dry weight of samples. For this reason, even though the water content calculation was performed for comparison, there were still differences in the reported results which may be related mainly to regional and environmental factor variations.

Mineral levels of marine organisms are influenced by a variety of factors such as species-specific differences, physicochemical parameters, foraging behavior, stress, or reproduction period. Changes in the environment are also important due to changes in feeding habits and potential exposure to minerals from anthropogenic sources. However, in this study, these variables can be ignored, since all samples were collected from the same location where *H. poli* coexist with *H. tubulosa* (Künili et al., 2016; Künili, 2017; Künili and Çolakoğlu, 2019). According to the reported values, significant changes are generally observed in particular minerals which are discussed above. Minerals are accumulated at varying levels in the body wall due to species-specific needs.. For example, higher accumulation of Ca and Mg in *H.poli* body wall may be associated with the presence of prominent ossicles which are unique structures for echinoderms, as well as Holothurians, On the other hand, higher Si and B levels, as explained above, are most likely related to thicker body wall, as a major portion of the of body wall is constituted by collagenous tissues which are synthesized in the presence of these minerals.

The mean concentrations of essential minerals and toxic metals in the samples of all seasons were summarized in Figure 3 (wet weight basis; mg/g – µg/kg) together with their reference daily intake or tolerable recommended/threshold values.

In this study, minerals given in Figure 3 were selected according to their importance in human nutrition and toxicity. The mean concentrations of these minerals among all seasons are given in Figure 3 with their recommended/tolerable (threshold) levels described by various authorities (EC, 2006; EFSA, 2015; FDA, 2016; TMFAL, 2002; WHO, 2012).

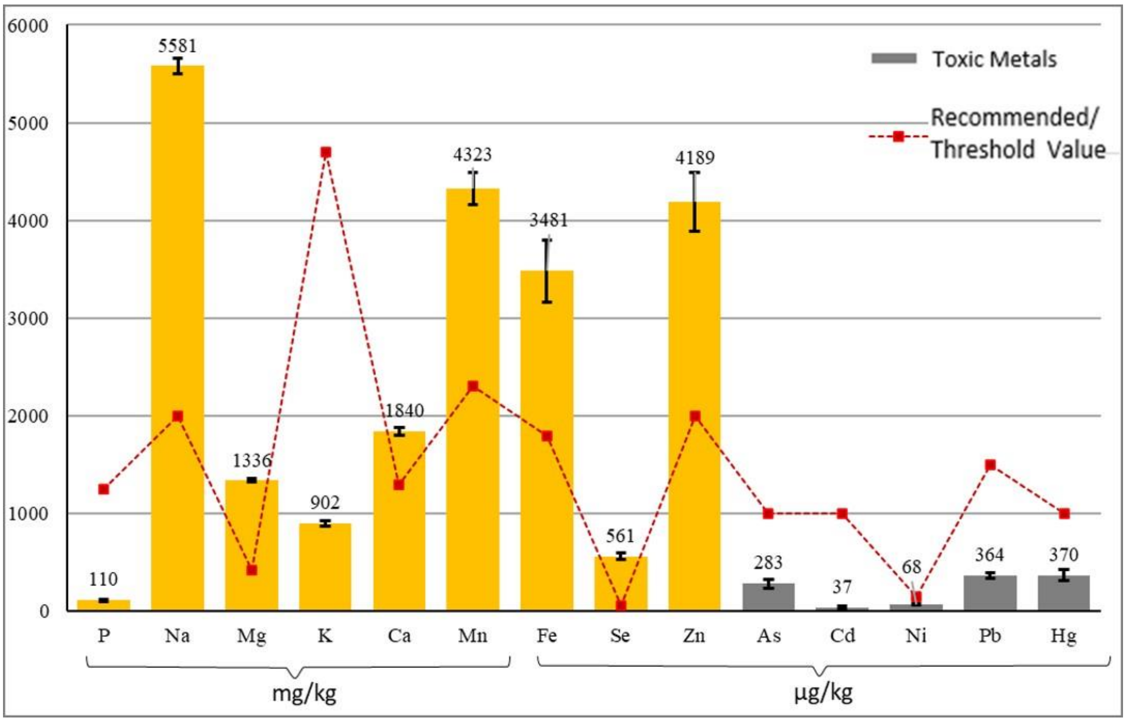

Figure 3. Mineral composition of *Holothuria poli* (mean of all seasons) with recommended daily intake or tolerable threshold values (recommended by FDA, WHO, and EFSA or enforced by TMFAL and EC Legislations)

According to the results, selected minerals that have a function in the body and are recommended for daily intake by the authorities were found to be higher than the threshold level with the exception of P (110 mg/kg) and K (902 mg/kg) which were found to be lower than the recommended values (Figure 3). Essential minerals help maintain routine human body functions by taking part in important physiological activities. Zn and Fe, for example, are important with respect to regulation of homeostasis, neural and physical development (Abbaspour et al., 2014; Brown et al., 2001). The Zn and Fe in the samples were above the minimum levels (11-18 mg/kg) recommended by the Food and Drug Administration (FDA, 2016). On the other hand, Mg and K are the other important minerals and their scarcity could lead to deficiency of muscle development and neuromuscular disorders along with cellular dysfunctions in oxidative phosphorylation, glycolysis, DNA transcription and protein synthesis (Rude, 1998; Rude et al., 1989). The mean concentrations of both minerals were above the minimum levels (33 mg/kg Mg – 35 mg/kg K) recommended (FDA, 2016). Mean level of Se in *H. poli* was also found to be higher than recommended values (18- 55 µg/kg). However, the daily intake of Se should not exceed 70 µg/kg a day and 400 µg/kg – 700 µg/kg may lead toxic reactions (Kieliszek and Błażejak, 2016). In this study, the mean concentration of Se was determined as 561 µg/kg and along with Se and other essential minerals, a 200 g portion of *H. poli* can meet the daily requirements of human body without exerting toxic effects.

In the marine environment, exposure to toxic metals can occur either at normal levels due to natural presence in seawater or at elevated levels as a result of industrialization which can cause food safety concerns. In this study, all toxic metal concentrations were found to be lower than the reported threshold levels for food safety (TMFAL, 2002; EC, 2006; EFSA, 2015).

Conclusion

Holothuria poli is a highly economic sea cucumber species and the dense populations of this species can be observed in the sampling area of the present study. Although they are not consumed in Turkey, sea cucumbers were heavily exploited during the last decade and sold to the international markets. This study was performed to determine the nutritional quality and meat yield which affect economical values of sea cucumbers. In addition, their mineral contents along with toxic metal levels which are indications of food safety also determined seasonally. As a result, *H. poli* has a high meat yield up to 66.9%, especially prior to the spawning period and the nutritional content fluctuates until the summer.

With respect to product quality and nutritional content, animals collected in the autumn had inferior qualities due to reduction in body mass and biochemical changes as a result of spawning.

The mineral composition may show variations by region, however, the species-specific differences are also important. *H. poli* can accumulate species-specific minerals such as Si, B, Mn, Zn, and Fe and toxic metals. However, mineral levels can be considered as safe in terms of of human consumption based on recommended and threshold levels. Further studies focusing on the understanding of this species' accumulation tendency of minerals, especially toxic ones and optimal utilization season in terms of product quality should be addressed in future studies.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Author Contributions

İ.E. Künili obtained samples and analysed data. F. Çolakoğlu contributed to study conception, design, and writing.

Ethics Approval

The material used in this article is invertebrate species therefore ethics committee approval is not required for this study.

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