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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

Seasonal Proximate Composition, Amino Acid and Trace Metal Contents of the Great Mediterranean Scallop (*Pecten jacobaeus*) Collected from the Gulf of Antalya

Erdinç VESKE[1]* **Ekrem Cem ÇANKIRILIGİL[1]** **Hijran YAVUZCAN YILDIZ[2]**
[1] *Sheep Breeding Research Institute, Department of Fisheries, Bandırma, Balıkesir, Türkiye*
[2] *Ankara University, Faculty of Agriculture, Department of Fisheries and Aquaculture, Ankara, Türkiye*

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*: https://orcid.org/0000-0002-4194-2120
: https://orcid.org/0000-0001-5898-4469
: https://orcid.org/0000-0001-6567-7467

***Corresponding author:**
Erdinç VESKE
Sheep Breeding Research Institute, Bandırma, Balıkesir, Türkiye
: erdinc.veske@tarimorman.gov.tr

Abstract: This study evaluated the seasonal nutrient content and trace element composition of the great Mediterranean scallop (*Pecten jacobaeus*), which is among the economic scallop species. The samples were obtained as by-catch from the trawler nets of commercial fishing boats operating in the Gulf of Antalya seasonally between 2017 and 2018. After determining the scallops' growth indices; proximate composition, amino acid and element analyses were carried out. According to the results, condition index and gonadosomatic index were highest in the summer, while meat yield was highest in autumn. The muscle tissue's crude protein and ash ratio decreased to a minimum in summer. Crude fat was determined at the highest level in the spring and decreased after the summer when the reproduction period was over ($P<0.05$). Total amino acid contents in muscle were found between 13.313±0.81 to 15.047±0.57 g/100g. Valine, phenylalanine and isoleucine decreased from autumn to summer ($P<0.05$), and no statistically significant change was found in amounts of tryptophan and threonine ($P>0.05$). Also, *P. jacobaeus* was found as rich in boron, zinc, and manganese. All trace elements measured in this study were found below the acceptable limits. Amongst the toxic metals, arsenic and mercury were not detected in the scallop tissues. Although cadmium and lead were not detected in muscle tissue, they were found below the acceptable limit values in the digestive gland.

Keywords: Bivalve, by-catch, essential amino acids, heavy metals, seafood safety.

Antalya Körfezi'nden Toplanan Akdeniz Deniz Tarağı (*Pecten jacobaeus*)'nın Mevsimsel Ham Besin Bileşimi, Amino Asit ve İz Metal İçerikleri

***Sorumlu yazar:**
Erdinç VESKE
Koyunculuk Araştırma Enstitüsü, Bandırma, Balıkesir, Türkiye
: erdinc.veske@tarimorman.gov.tr

Öz: Bu çalışmada, ekonomik tarak türleri arasında yer alan Akdeniz deniz tarağı (*Pecten jacobaeus*)'nın mevsimsel besin içeriği ve iz metal içerikleri değerlendirilmiştir. Örnekler Antalya Körfezi'nde faaliyet gösteren ticari balıkçı teknelerinin trol ağlarından hedef dışı av olarak 2017-2018 yılları arasında alınmıştır. Deniz taraklarının bazı büyüme indeksleri belirlendikten sonra, ham besin bileşimi, amino asit ve element analizleri gerçekleştirilmiştir. Sonuçlara göre; kondisyon indeksi ve gonadosomatik indeks en yüksek yaz mevsiminde, et verimi ise en yüksek sonbaharda tespit edilmiştir ($P<0,05$). Yaz mevsiminde kas dokusunun ham protein ve kül oranı en az miktarlarda bulunmuştur. Ham yağ miktarı ise ilkbaharda en yüksek düzeyde belirlenmiş olup üreme döneminin bittiği yaz mevsiminden sonra azalmıştır ($P<0,05$). Kas dokunun toplam amino asit içeriği ise 13,313±0,81 ile 15,047±0,57 g/100g arasında tespit edilmiştir. Valin, fenilalanin ve izolösin miktarları sonbahardan yaz mevsimine doğru azalış gösterirken ($P<0,05$), triptofan ve treonin miktarlarında istatistiksel olarak anlamlı bir değişim saptanamamıştır ($P>0,05$). Ayrıca, *P. jacobaeus*'un bor, çinko ve manganez açısından zengin olduğu tespit edilmiştir. Bu çalışmada tespit edilen tüm iz elementler kabul edilebilir limit değerlerin altında bulunmuştur. Toksik metallerden arsenik ve cıva ise tarak dokularında tespit edilememiştir. Kadmiyum ve kurşun ise kas dokusunda tespit edilememelerine rağmen, miktarları sınır değerlerin altında olsa da sindirim kesesinde tespit edilmiştir.

Anahtar kelimeler: Ağır metallar, çift kabuklular, esansiyel amino asitler, hedef dışı av, su ürünleri güvenliği.

INTRODUCTION

Scallops are considered one of the palatable seafood products with low fat and high protein levels by consumers. The nutritional value of the essential amino acids, the high rate of the long-chained polyunsaturated fatty acids, highly digestible proteins and the mineral ingredients make the scallops a very beneficial food source (Manthey-Karl et al., 2015). With these benefits and the high consumer demand, several scallop species were evaluated in the seafood processing sector (Beaumont & Gjedrem, 2007; Biandolino et al., 2020), and the marketing of scallops in Europe has increased significantly in recent years (FAO, 2020). Thus, the high economic value of the scallops sustained them to become a subject of both fisheries and aquaculture studies (Barber & Blake, 2016). Although the procured quantity of scallops presents some declines in the last decade, 810 million tons of produced scallops were recorded in 2019. The trading value of the scallops was estimated to be 965 million USD in 2008, which increased to 1.65 billion USD in 2018 (FAO, 2017; 2020). According to FAO (2020), the total import value is expected to reach 2.5 billion USD within a decade.

The Mediterranean Sea has rich resources of economic scallop species such as *Pecten jacobaeu*s, *Flexopecten glaber, Aequipecten opercularis* and *Mimachlamys varia* (Erdem et al., 2006). Among these species, the great Mediterranean scallop (*Pecten jacobaeus*) is unique because it can be obtained from both captured and aquaculture operations (Beaumont & Gjedrem, 2007; FAO, 2020). This species is distributed from Eastern Atlantic to the Mediterranean Sea and lives at 0-500 m depth. The shell valves of the species are asymmetrical and have prominent 15-18 ribs arranged in radial (Palomares & Pauly, 2022). The ribs are usually fan-shaped, and these can be equal, or the front can be larger (Pechenik, 1996). The foot is small and byssus. Scallops are mostly hermaphrodites, and the sexual cycle spreads over the year (Mattei & Pellizzato, 1996; Palomares & Pauly, 2022). They find suitable mossy or rocky bottoms during the breeding season and create the ideal environment for spawning (Barnes, 1987). They usually live attached to a substrate by byssus threads. Many species can move short distances by suddenly opening and closing their shells. The anterior adductor muscle is shrunken. However, the posterior adductor muscle is quite large and consumed as food (Erdem et al., 2006; Serb, 2016). Adductor muscle has a high amount of omega-3 fatty acids, proteins and beneficial trace elements in adequate amounts (Krzynowek & Murphy, 1987; Tan et al., 2021). Although several comprehensive studies on the chemical compositions of other economic scallop species have been carried out for species of *Flexopecten glaber*, *Pecten maximus*, *Patinopecten yessoensis* (Krzynowek & Murphy, 1987; Pazos et al., 1997; Li et al., 2010; Berik et al., 2017), studies on *P. jacobaeus* are limited. For the seafood sector, the nutrient composition and elemental contents are among the most important subjects to be assessed in the scallop species.

The main criteria in assessing seafood products are the nutritional quality of fresh scallops and any changes during the transportation, processing, and storage operations. Identifying the losses in the nutrition level of the food is a challenging issue, and the original nutritional composition and properties, as mentioned above, can be considered valuable tools for identifying adulterations that cause quality losses (Manthey-Karl et al., 2015). Besides, the chemical quality of the scallop species can be changed according to environmental conditions and gonadal development (Barnes, 1987; Pechenik, 1996; Barber & Blake, 2016). Therefore, it is vital to know the seasonal changes in the biochemical composition of the scallops. Another biochemical factor that directly affects benthic organisms is the element variations in the marine environment (Stankovic et al., 2014). Especially in recent years, rapid industrialization and environmental pollution caused by human activity endanger the food safety of the marine environment (Belcheva et al., 2007; Stankovic et al., 2014). Possible elemental contaminations in the environment affect the elemental composition of aquatic creatures, such as scallops that take elements directly from the water column as filter feeders (Bustamante & Miramand, 2005; Broadaway, 2012). Besides the Marine Strategy Framework Directive (MSFD, 2008/56/EC), the Task Group 9 report, which comprised the period between 2010-2020, stated that the cadmium, lead, and mercury levels in fish and other seafood should be monitored in future food security studies even if they were studied in the same species and location before (Swartenbroux et al., 2010). Besides, Kruzynski (2004) highlighted the significance of monitoring the cadmium levels in market products of scallops due to their digestive gland being located in the majority of entire cadmium compositions.

This study evaluated the seasonal nutrition content and trace metal composition of the great Mediterranean scallop *Pecten jacobaeus,* which is widely distributed in the Mediterranean and listed in high economic valued scallop species. The article's topic is very important for future food security studies since the consumption and production of species like *P. jacobaeus* show an increasing trend and thus could directly affect the seafood processing sector and human nutrition studies.

MATERIAL AND METHOD

Sampling Studies: The study material was selected as the great Mediterranean scallop, *Pecten jacobaeus*. Scallop individuals were obtained from bottom trawl operations (cod-end mesh size 40 mm) as a by-catch between 2017 and 2018 (October, January, April and July) from 6 stations in the Gulf of Antalya, the Mediterranean Sea. Due to the migratory behaviour of the species from shallow to deep waters in cold seasons, scallops were collected from different stations. In Summer and Spring, scallops were collected from two stations, while in Autumn and Winter, they were found only in one station each season. Sampling stations are shown in Figure 1. In this research, 50 scallops were studied in each season.

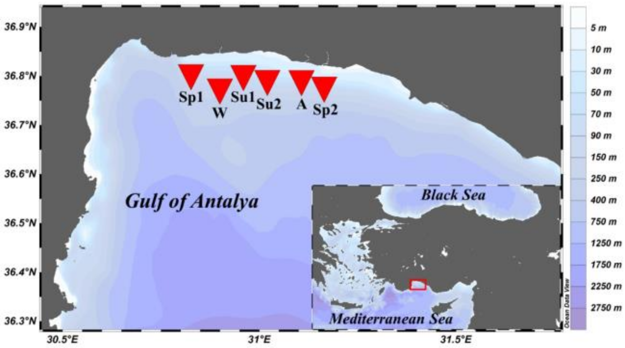

Figure 1. Sampling stations of the great Mediterranean scallop (*Pecten jacobaeus*) A: The sampling station in autumn (36°47'26.16"N, 31°6'27.36"E), W: The sampling station in winter (36°46'24.24"N, 30°54'0.72"E), Sp1: The first sampling stations in spring (36°48'9.36"N, 30°49'36.84"E), Sp2: The second sampling stations in spring (36°46'37.92"N, 31°9'54.36"E), Su1: The first sampling station in summer (36°48'3.96"N, 30°57'35.64"E), Su2: The second sampling station in summer (36°47'27.24"N, 31°1'14.52"E). The sampling station map was drawn with Ocean Data View Software (ODV) (Schlitzer, 2015).

Determination of Growth Indices: Firstly, scallops were weighted with 0.001 precision, and the total weight (with shell) was determined. In the following, shell valves were removed, and whole fresh tissue, adductor muscle and gonadal tissue were weighed individually. Condition index (CI) was calculated according to Lucas & Beninger (1985), meat yield (MY) was calculated with the equation of Öztan (2005), and gonadosomatic index (GSI) was calculated according to Ricker (1975) as follows:

$$CI = (W_0/W_T) \times 100$$

W_0: weight of whole fresh scallop tissues, W_T: total scallop weight with shells.

$$MY = (W_A/W_T) \times 100$$

W_A: weight of adductor muscle, W_T: total scallop weight with shells.

$$GSI = (W_G/W_T) \times 100$$

W_G: weight of gonad, W_T: total scallop weight with shells.

Determination of Proximate Composition: Proximate composition analyses were carried out seasonally in the adductor muscle, the edible part of the scallops. In moisture analysis, homogenized samples were weighed into petri plates, and samples were dehydrated at 100 °C for 24 hours in a drying oven. In crude ash analysis, weighed samples were burned with a muffle furnace at 600 °C for 6 hours until the samples were completely burned. Finally, moisture and crude ash contents were calculated according to AOAC (2000). Crude protein content was determined with the Kjeldahl procedure (AOAC, 2000). Samples were digested with H_2SO_4 and Kjeldahl catalyst containing selenium until the samples were completely hydrolyzed. Obtained samples were distilled with NaOH and titrated with 0.1 N HCl. In crude fat analysis, tissues were mixed with methanol-chloroform complex (2:1) for 12 hours for fat extraction. Finally, mixtures were evaporated with a vacuum evaporator at 55 °C, and crude fat content was calculated according to Folch et al. (1957).

Amino Acid Analysis: In amino acid analysis, the muscle tissue of the scallop was digested with 3.67 N HCl at 100 °C for 24 hours in a drying oven as a pre-treatment, according to Çankırılıgil et al. (2020). After digestion, hydrolysates were filtered with 0.45 µm PTFE syringe filters and diluted with deionized water as 10^{-1}. Filtrates were transferred into 2 ml amber vials, and derivatization was performed automatically with borate buffer, OPA and FMOC reagents in the Agilent HPLC system. According to Henderson et al. (2000), amino acid analyses were carried out. In amino acid separation, a C18 amino acid column (Zorbax Eclipse AAA) and a mobile phase consisted of 40 mM Na_2HPO_4 (A) adjusted to 7.8 pH and the mixture of MeOH:ACN:H_2O (45%:45%:10%) (B) were used. Gradient elution stages of the mobile phase were follows; A:100%, B:0% in 1.9 min, A:43%, B:57% in 18.1 min, A:0%, B:100% in 18.6 min, A:0%, B:100% in 22.3 min, A:100%, B:0% in 23.2 min, with 2 ml/min flow rate. The detection was performed with a diode array detector at two wavelengths, 338 nm for OPA bonded amino acids and 262 nm for FMOC bonded amino acids.

Trace Metal Analysis: Scallops are consumed as whole flesh tissue with all organs or as adductor muscle (Berik et al., 2017). In scallops, elements were primarily accumulated in the digestive gland, and the consumers digested this tissue in the first consumption option. Thus element analyses were carried out with adductor muscle and digestive gland to evaluate possible elemental risks caused by consuming options. Element analyses were carried out according to NMKL (2007). Also, the 9th task group of the Marine Strategy Framework Directive implications were applied to avoid secondary contaminations and perform standardized analysis (Swartenbroux et al., 2010). Firstly, tissue samples were digested with 7 ml HNO_3 in Milestone Ethos Easy microwave at 160 °C for 2 hours. Afterwards, obtained mixtures were filtered and diluted with deionized water (1:1). Finally, filtrates were analyzed by an inductively coupled plasma optical emission spectrometry (ICP-OES) in Namık Kemal University, Central Research Laboratory. In analyses; arsenic (As), boron (B), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), tin (Sn) and zinc (Zn) contents were evaluated.

Data evaluation: All analyses were carried out in triplicate, and obtained data were expressed as mean value ± standard error. The normality of the mean values was calculated with the Anderson-Darling test, while homogeneity was calculated with Levene Test. The one-way ANOVA method analyzed differences between mean values of growth characteristics, proximate composition parameters, amino acid, and trace element contents. The significance level was accepted as 0.05 (Zar, 1999). All statistical analyses were carried out by IBM SPSS Statistics 23 software.

RESULTS

Condition index (CI), meat yield (MY) and gonadosomatic index (GSI) of the great Mediterranean scallop (*Pecten jacobaeus*) are shown in Table 1. CI and GSI were lowest in autumn, while they were found highest in the summer. CI increased from 37.35±0.45% to 42.42±0.51%, while GSI increased from 3.41±0.24% to 10.24±0.52% in the summer, similarly (P<0.05). On the contrary, meat yield (MY), expressed as the ratio of the adductor muscle to the total weight, was lowest in the spring with 12.27±0.19%, while it was highest in the autumn with the ratio of 15.21±0.14% (P<0.05).

The proximate composition of the great Mediterranean scallop (*Pecten jacobaeus*) is shown in Table 2. According to the results, *P. jacobaeus* has 78.16±0.30% to 79.63±0.36 moisture content in samples. The highest moisture was found in spring and summer, while the lowest was detected in autumn and spring. Similarly, crude ash ratios were highest and lowest in exact seasons, ranging from 1.22±0.02% to 1.55±0.16%. The highest crude protein ratio was detected at 14.28±0.32% in the autumn, and it was found to be lowest at 12.57±0.21% in the spring. Crude fat ratios of the *P. jacobaeus* were found between 1.05±0.08% and 2.03±0.11%. The highest crude fat was detected in spring, while the lowest was in autumn (P<0.05).

Table 1. Some growth indices of great Mediterranean scallop (*Pecten jacobaeus*) (%).

	Autumn	Winter	Spring	Summer
CI	37.35±0.45^{d}	39.13±0.42^{c}	40.51±0.37^{b}	42.42±0.51^{a}
MY	15.21±0.14^{a}	14.36±0.30^{b}	12.27±0.19^{c}	13.98±0.24^{b}
GSI	3.41±0.24^{d}	6.32±0.44^{c}	8.36±0.63^{b}	10.24±0.52^{a}

Values expressed as mean value (%) ± standard error and different superscripts in a line represent statistical differences. MY: meat yield, CI: condition index, GSI: gonadosomatic index.

Table 2. Proximate composition of great Mediterranean scallop (*Pecten jacobaeus*) muscle.

	Autumn	Winter	Spring	Summer
Moisture	78.41±0.34^{b}	78.16±0.30^{b}	79.42±0.41^{a}	79.63±0.36^{a}
Protein	14.28±0.32^{a}	13.68±0.18^{ab}	12.57±0.21^{c}	13.45±0.24^{b}
Fat	1.05±0.08^{d}	1.45±0.05^{c}	2.03±0.11^{a}	1.77±0.06^{b}
Ash	1.26±0.04^{b}	1.22±0.02^{b}	1.38±0.10^{a}	1.55±0.16^{a}

Values expressed as mean value (%) ± standard error and different superscripts in a line represent statistical differences.

The seasonal amino acid composition of the great Mediterranean scallop (*Pecten jacobaeus*) adductor muscle is shown in Table 3. Asparagine (Asn) and glutamine (Gln) which can be found as aspartic acid (Asp) and glutamic acid (Glu) in the analysis, were evaluated together as Asp+Asn and Glu+Gln. Besides, these amino acids were the most abundant in the *P. jacobaeus* muscle tissue. All essential amino acids were found in the *P. jacobaeus* muscle tissue in all seasons. The highest essential amino acids were detected as lysine, threonine and leucine, with amounts greater than 1 g/100g in all seasons. Besides, *P. jacobaeus* has considerable valine, methionine, phenylalanine, isoleucine and histidine. Amongst all detected 18 amino acids, the lowest one was found as tryptophan in the range of 0.022±0.004 g/100g to 0.031±0.006 g/100g. Thus, no statistical differences were determined in the tryptophan contents between seasons (P>0.05). Similarly, threonine contents were statistically the same between seasons (P>0.05). However, most of the amino acids decreased from autumn to summer. In autumn, the amounts of histidine, glycine, alanine, tyrosine, cysteine, valine, methionine, phenylalanine and isoleucine were found as highest, and they were decreased until summer (P<0.05). On the contrary, serine and lysine were the only amino acids that increased from autumn to summer. Finally, total amino acid content was highest in the autumn with the content of 15.047±0.57 g/100g, and it was found to be lowest in the summer at 13.313±0.81 g/100g, with gradually reducing throughout the year (P<0.05).

Seasonal trace metal contents of great Mediterranean scallop (*Pecten jacobaeus*) are shown in Table 4. Results were expressed as adductor muscle and digestive gland, considering two consumption options. According to the results, the most abundant trace metals were detected as zinc (Zn), manganese (Mn), boron (B), copper (Cu), nickel (Ni) and chromium (Cr), respectively. Thus, these elements were found in all tissues, while cadmium (Cd) and lead (Pb) were detected only in the digestive gland. However, Arsenic (As), cobalt (Co), mercury (Hg) and tin (Sn) were detected in neither adductor muscle nor digestive gland. Zn, B and Cr contents increased from autumn to summer, reaching the highest values in adductor muscle (P<0.05). On the contrary, they were found lowest in summer sampling in the digestive gland (P<0.05). In the summer, Cu, Mn and Ni contents were lowest in the adductor muscle and digestive gland (P<0.05). The toxic metals, Cd and Pb, detected only in the digestive gland, were highest in the summer (P<0.05). Cd amounts ranged from 0.055±0.007 g/100g to 0.119±0.008 g/100g, while Pb contents were found between 0.018±0.001 g/100g and 0.028±0.002 g/100g.

Table 3. Seasonal amino acid compositions of great Mediterranean scallop (*Pecten jacobaeus*) adductor muscle (g/100g).

Amino acids	Autumn	Winter	Spring	Summer
ASP+ASN	2.194±0.033^{b}	2.223±0.038^{ab}	2.278±0.039^{a}	2.026±0.050^{c}
GLU+GLN	1.851±0.021^{b}	2.096±0.074^{a}	1.764±0.034^{c}	1.620±0.049^{d}
SER	0.292±0.024^{c}	0.311±0.021^{c}	0.387±0.017^{b}	0.538±0.042^{a}
HIS	0.594±0.011^{a}	0.552±0.019^{b}	0.419±0.020^{c}	0.407±0.017^{c}
GLY	1.139±0.025^{a}	1.113±0.051^{ab}	1.099±0.056^{ab}	1.010±0.046^{b}
THR	1.556±0.064^{a}	1.526±0.080^{a}	1.484±0.071^{a}	1.493±0.056^{a}
ALA	0.341±0.024^{a}	0.323±0.019^{a}	0.260±0.015^{b}	0.205±0.022^{c}
TYR	1.179±0.015^{a}	1.123±0.021^{b}	1.155±0.023^{ab}	0.902±0.025^{c}
CYS	0.258±0.012^{a}	0.186±0.013^{b}	0.176±0.020^{b}	0.154±0.09^{c}
VAL	0.520±0.025^{a}	0.510±0.018^{a}	0.426±0.021^{b}	0.366±0.029^{c}
MET	0.642±0.041^{a}	0.594±0.035^{a}	0.459±0.034^{b}	0.493±0.031^{b}
TRP	0.025±0.005^{a}	0.022±0.004^{a}	0.031±0.006^{a}	0.025±0.004^{a}
PHE	0.738±0.031^{a}	0.662±0.039^{b}	0.529±0.042^{c}	0.500±.033^{c}
ISO	0.524±0.020^{a}	0.506±0.018^{a}	0.401±0.014^{b}	0.385±0.017^{b}
LEU	1.389±0.067^{a}	1.261±0.057^{b}	1.111±0.054^{c}	1.277±0.063^{b}
LYS	1.806±0.078^{ab}	1.730±0.079^{b}	1.675±0.061^{b}	1.911±0.054^{a}
TAA	**15.047±0.57^{a}**	**14.738±0.69^{b}**	**13.655±0.35^{c}**	**13.313±0.81^{d}**

Values expressed as mean value (g/100g) ± standard error and different superscripts in a line represent statistical differences. ASP: aspartic acid, ASN: asparagine, GLU: glutamic acid, GLN: glutamine, SER: serine, HIS: histidine, GLY: glycine, THR: threonine, ALA: alanine, TYR: tyrosine, CYS: cysteine, VAL: valine, MET: methionine: TRP: tryptophan, PHE: phenylalanine, ISO: isoleucine, LEU: leucine, LYS: lysine, TAA: total amino acids.

DISCUSSION AND CONCLUSION

In scallops, gonadal development and reproduction can affect species or environmental conditions (Barber & Blake, 2016; Genez et al., 2015). The scallop species' reproduction period starts from April to September in the Mediterranean Sea (Barber & Blake, 2016; Marceta et al., 2016). Most reproduction occurs mid-summer, especially in July and August (Marceta et al., 2016). In our research, gonadosomatic index (GSI) values indicate gonadal development, regularly increasing throughout the year and are found to be highest in the summer as expected (P<0.05). In parallel with gonadal development, the scallop's total flesh weight also increases, which causes an increase in the condition index till summer (P<0.05). The meat yield decreases towards the reproduction period due to the area covered by the muscle tissue being relatively less by the enlargement of the gonads (P<0.05).

Condition index, meat yield and gonadosomatic index are essential parameters to evaluate the commercial quality of scallops, and they directly correlated with the nutritional changes in the scallop tissues during reproduction (Berik & Çankırılıgil, 2013; Biandolino et al., 2020; Orban et al., 2002).

Scallops are beneficial nutritional profiles in lipids and protein ratios, especially in the adductor muscle, which presents a healthier nutritional profile than the whole flesh scallop (Berik et al., 2017; Prato et al., 2018). The muscle of scallop species has approximately 75–80% moisture (Manthey-Karl et al., 2015), while they have moderate protein and low-fat contents (Berik et al., 2017; Biandolino et al., 2020; Prato et al., 2018), similar to our results. In spring, crude fat content increased to 2.03±0.11% at its highest and decreased parallel with the reproduction period. In scallops, energy values originating from macromolecules just as lipids, carbohydrates, and proteins increase just before reproduction due to the high energy requirement needed for gametogenesis (Barber & Blake, 2016; Marceta et al., 2016; Telahigue et al., 2013a). Significantly crude fat content can be increased in the muscle tissue, and those lipids are used to compensate for energy demand caused by gametogenesis (Berik & Çankırılıgil, 2013; Telahigue et al., 2013a; Telahigue et al., 2013b). Besides, total energy gained by the gonads came from adductor muscle in the ratio of 63-99% and caused degradation of the protein ratio in the scallops (Brokordt et al., 2000).

Table 4. Seasonal trace metal contents of great Mediterranean scallop (*Pecten jacobaeus*) (g/100g).

	Adductor Muscle				Digestive Gland			
	Autumn	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**
As	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
B	0.316±0.008^{b}	0.327±0.007^{b}	0.346±0.010^{a}	0.338±0.007^{a}	0.267±0.005$^{\alpha}$	0.251±0.006$^{\beta}$	0.249±0.005$^{\beta}$	0.237±0.006$^{\gamma}$
Cd	<0.003	<0.003	<0.003	<0.003	0.067±0.012$^{\beta}$	0.055±0.007$^{\beta}$	0.104±0.011$^{\alpha}$	0.119±0.008$^{\alpha}$
Co	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Cr	0.008±0.001^{b}	0.009±0.001^{ab}	0.011±0.001^{a}	0.010±0.001^{ab}	0.017±0.001$^{\beta}$	0.020±0.002$^{\alpha\beta}$	0.023±0.002$^{\alpha}$	0.018±0.002$^{\beta}$
Cu	0.056±0.003^{a}	0.050±0.002^{b}	0.048±0.002^{b}	0.039±0.003^{c}	0.185±0.009$^{\alpha}$	0.169±0.006$^{\beta}$	0.179±0.007$^{\alpha\beta}$	0.155±0.004$^{\gamma}$
Hg	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Mn	0.357±0.004^{b}	0.374±0.006^{a}	0.346±0.005^{c}	0.334±0.004^{d}	0.843±0.011$^{\beta}$	0.851±0.013$^{\beta}$	0.809±0.007$^{\gamma}$	0.913±0.010$^{\alpha}$
Ni	0.025±0.002^{b}	0.027±0.001^{a}	0.036±0.002^{a}	0.019±0.001^{c}	0.062±0.002$^{\beta}$	0.052±0.003 $^{\gamma}$	0.074±0.002$^{\alpha}$	0.059±0.003$^{\gamma}$
Pb	<0.008	<0.008	<0.008	<0.008	0.018±0.001$^{\gamma}$	0.022±0.002$^{\beta}$	0.026±0.002$^{\alpha\beta}$	0.028±0.002$^{\alpha}$
Sn	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Zn	3.152±0.039^{b}	3.051±0.032^{c}	3.225±0.042^{a}	3.271±0.044^{a}	2.987±0.031$^{\alpha}$	2.963±0.047$^{\alpha}$	2.846±0.040$^{\beta}$	2.856±0.033$^{\beta}$

Values are expressed as mean (g/100g), and different superscripts in a row (a, b, c, d for muscle and α, β, γ for the digestive gland) indicates statistical differences (P<0.05).
The LOD values were given for the elements below the detection limits.

According to amino acid analyses, 18 amino acids were detected in the adductor muscle. Among these amino acids, asparagine (Asn) and glutamine (GLN) can be digested into aspartic acid (Asp) and glutamic acid (Glu), respectively, with the high heat and low pH conditions in the pre-treatment of the amino acid analysis (Varlık et al., 2004; Çankırılıgil et al., 2020). Thus, they were evaluated as Asp+Asn and Glu+Gln to get more acquired results. In this research, Asp+Asn, Glu+Gln, lysine, threonine, and leucine were highest in the adductor muscle. These amino acids were also found high in similar studies focused on the other economic scallop species such as *Chlamys nobilis*, *Flexopecten glaber*, and *Mizuhopecten yessoensis* (Hao et al., 2015; Han et al., 2019; Vural & Acarli, 2021; Li et al., 2022). These amino acids are generally detected in high amounts in seafood and are responsible for the taste (Erkan et al., 2011; Kumar et al., 2011). Tryptophan is also very vulnerable to high temperature and low pH and may be lost entirely in the analysis (Cuq & Firedman, 1989). Therefore, tryptophan was the lowest amino acid in the scallop muscle in all seasons. All other essential amino acids except tryptophan, such as threonine, valine, methionine, phenylalanine, isoleucine, leucine, lysine and histidine, were detected in all groups. However, the majority of the essential amino acids and total amino acid content were decreased throughout the summer. The decrease in the protein and amino acids can explain gametogenesis (Brokordt et al., 2000; Telahigue et al., 2013a). Brokordt et al. (2000) stated that gonadal development could cause the reproduction expanse of muscle protein in the scallops. That is why the crude protein and total amino acid contents were degraded during the reproduction period of *P. jacobaeus* ($P<0.05$). On the contrary, serine increased parallel with gametogenesis and was detected approximately 1.8 times higher in summer than in autumn ($P<0.05$). According to Zandee et al. (1980)'s research on *Mytilus galloprovincialis*, serine was detected at the highest amount in summer, while glycine and aspartic acid were found as the lowest, similar to our results. This situation is explained by the bivalves adapting to changing seasonal environmental conditions by giving an osmoregulatory response (Zandee et al., 1980). Besides, Yao et al. (2020) state that amino acids can supply energy during such adaptation. It is also expected that glycine amount will increase while serine decrease due to glycine synthesis from stored carbohydrates from serine caused by long-term starvation (Zandee et al., 1980). The opposite situation indicates the presence of protein-rich food in the marine environment (Allen, 1961; Zandee et al., 1980). So, it can be said that sampling stations have adequate nutrient sources for scallop growth and reproduction rather than any nutrient shortage.

Scallops are suspended feeders that live in the seabed in a semi-buried form of benthos. Primary production directly affects the feeding mechanism of the scallops with the changing environmental parameters such as riverine inputs, a quantity of light penetration, and the currents in a coastal ecosystem (Rossi et al., 2004). Phytoplankton is the essential diet component of the scallops; however, other sources such as suspended and sedimentary particulate organic matter, bacterial community, microphytobenthic organisms, and zooplankton can also become significant elements for the diet composition (Egzeta-Balic et al., 2012; Pechenik, 1996). Scallop species accumulate metals in tissues through their feeding strategy, especially some toxic elements, particularly cadmium, even in clean environments (Francesconi et al., 1993; Uthe & Chou, 1987). The accumulation of the metals pertains to tissues for scallop species, and each can differ in metal toxicity (Nardi et al., 2018). In our research, a similar element accumulation pattern was observed. Except for Zn and B, elements were detected higher in the digestive gland than in adductor muscle ($P<0.05$). Cr, Cu, Mn, and Ni accumulated approximately 2 to 4 times higher in the digestive gland than in muscle tissue ($P<0.05$). However, Zn and B were detected in lower values in the digestive gland ($P<0.05$), especially in the spring and summer when reproduction takes place. In reproduction season, Zn and B were found to be lowest in the digestive gland and highest in the adductor muscle ($P<0.05$). Zinc is one of the highest trace metals existing in the scallop species (Pan & Wang, 2008), and it primarily accumulated in the gonadal tissue in the reproduction period (Greig et al., 1978). Besides, the scallop's muscle tissue is a rich source of boron (Berik et al., 2017), and boron content can be increased with elevated water temperatures (Tate et al., 2017). Thus, Zn and B were taken by feeding and may have been used for reproduction parallel with growing, while stored elements in muscle tissue may not have been needed. In future studies, elemental accumulations of other tissues such as gonad, gill and mantle should be examined to make further comments on these accumulation patterns. Therefore, the quantity of the accumulated metal content in tissue can increase with the growth of the scallops (Belcheva et al., 2006). In our research, Cd and Pb have detected only the digestive gland. They were accumulated in the digestive gland parallel with scallop growth until summer ($P<0.05$). Similarly, Berik et al. (2017) stated that the scallop's muscle tissue was rich in beneficial macro and microelements, while toxic metals were found below the acceptable limits stated by the legislation. However, it was determined that the digestive gland contains 300 times more cadmium than muscle tissue (Berik et al., 2017). Besides, Prato et al. (2008) stated that cadmium is the primary toxic metal that can accumulate in high amounts in the scallop species. Belcheva et al. (2006) reported that cadmium and calcium intakes are related; therefore, excess cadmium can be found in the scallop digestive tissues. Thus, to reduce elemental risks and ensure food safety, scallops should be consumed as only adductor muscle after the digestive gland and other organs are separated (Belcheva et al., 2006; Berik & Çankırılıgil, 2013; Berik et al., 2017).

In conclusion, the results of our study showed that *P. jacobaeus* is an important marine food source with essential amino acids in ideal proportions and low fat and moderate protein ratios. Besides, scallop muscle tissue has some beneficial microelements such as Zn, B and Mn in significant amounts. Toxic metals, Cd, Pb, Hg, and As, were not detected in adductor muscle, while Cd and Pb were detected in the digestive gland. Cd and Pb content of the digestive glands were found below the legal limits, but it is safer to consume the scallops solely as an adductor muscle after removing the digestive gland. Although there is a decrease in some amino acids and trace elements depending on the breeding period, scallops were evaluated as quite nutritious, especially in winter and autumn.

ETHICAL STATEMENT

Since bivalves are invertebrates, ethics committee approval is not required within the scope of the "Regulation on the Welfare and Protection of Aquatic Vertebrates Used for Scientific Purposes". However, all studies were carried out according to the principles of ARRIVE (Animal Research: Reporting of in Vivo Experiments) and the ethical rules specified in the European Union's directive no: 2010/63/EU.

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