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Determination of Seasonal Vitamin and Mineral Contents of Sea Bream (*Sparus aurata* L., 1758) Cultured in Net Cages in Central Black Sea Region

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Abstract

This study aimed to determine the seasonal vitamin and mineral contents of sea bream (*Sparus aurata*) cultured in net cages in Central Black Sea region. The average seasonal A, D_3, and E vitamins values in fish meat were between 0.27 ± 0.02–0.60 ± 0.00, 0.98 ± 0.01–1.70 ± 0.00, and 3.10 ± 0.14–6.00 ± 0.21 mg/kg, respectively ($p < 0.05$). The average seasonal Ca, Fe, K, Mg, Na, P, Zn, and Se values in fish meat were between 276.90 ± 0.99–1788.50 ± 51.27 ($p < 0.05$), 3.50 ± 0.12–4.47 ± 0.18 ($p > 0.05$), 4244.50 ± 8.84–4761.50 ± 1.06 ($p < 0.05$), 251.55 ± 2.55–312.65 ± 11.42 ($p < 0.05$), 56.49 ± 0.04–128.75 ± 0.18 ($p < 0.05$), 2234.50 ± 15.20–2619.00 ± 7.07 ($p < 0.05$), 5.62 ± 0.10–15.30 ± 0.22 ($p < 0.05$), and 0.30 ± 0.00–0.38 ± 0.01 mg/kg ($p > 0.05$), respectively. As a result, it can be concluded that sea bream cultured in the Central Black Sea region is a rich source of nutrients in terms of vitamins and mineral matters, and fish size, feed quality, and the environmental factors are influential on the contents of vitamin and mineral substances in the fish tissue.

Keywords Sea bream · *Sparus aurata* · Black Sea · Vitamin · Mineral matters

Introduction

It is known that the production of aquatic products has been decreasing by fishing while it has been increasing by aquaculture. It is predicted that until 2030, both aquatic products obtained by aquaculture and fisheries will be equalized in the world [1]. Accordingly, it is estimated that production of freshwater fish like carp (*Cyprinus carpio*) and rainbow trout (*Oncorhynchus mykiss*), marine fish like sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*), and other alternative fish species will also increase in Turkey. Countries focus on the culture of fish species that are easy to produce and sustainable. The high economic value of sea bream, one of the most produced Mediterranean fish species, with high salinity tolerance, increases the importance of this species in the aquaculture sector.

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Sea bream production, which was reflected to the statistics as 10 t in the 1970s in the world, reached 136,506 t in 2015 [2]. While 55.7% of the production came from Europe and 44.3% from Asian countries, Turkey is also a leader position in sea bream production in the world with 51,844 t (38% in 2015) [3].

Vitamins and minerals are known as micronutrients and necessary for the cell metabolism and therefore for the physiological development of living organisms. Thus, people are taking vitamins or mineral supplements daily in order to improve the quality of life and the quality of their mental and physical activities. Fish and other aquatic products with rich contents of vitamins, mineral matters, and trace elements have a distinctive importance in the healthy nutritional model of human [4, 5].

Of all 90 naturally occurring inorganic elements, 29 are considered to be essential for all cultured fish species [6]. Micro minerals such as calcium (Ca), potassium (K), magnesium (Mg), sodium (Na) and phosphorus (P), and micro minerals such as copper (Cu), iron (Fe), iodine (I), manganese (Mn) selenium (Se), and zinc (Zn) are very important elements for fish and they are the minerals that must be found in feeds for cultured species [7]. Vitamins are organic compounds required in trace amounts from an exogenous source for normal growth, reproduction, and health. A few vitamins can be partially synthesized from other essential nutrients if these are present in sufficient amounts [8]. Especially the enrichment of feeds with vitamins helps to reduce the stress that may arise by contributing to the health and development of fish [9]. It was reported that vitamin C has a positive effect on reducing stress in fish [10]; vitamin E, a fat-soluble vitamin, is an antioxidant source that prevents oxidative damage and protects the nervous system in the brain against oxidative stress [11, 12]; vitamin A is a carotenoid source and preventing the reduction of mucus and phospholipid levels in the stomach mucosal barrier caused by stress [13]; vitamin D plays an important role in the strengthening of the immune system [14], and inhibits oxidative stress in the brain, has an immunomodulatory effect, and has a neuroprotective effect on fish [15, 16].

The Aegean region, where the most intensive marine fish farming is done in Turkey, with both water temperature and physical structure, provides ideal environmental conditions for the aquaculture sector. However, it has been predicted that sea bass farming could be carried out in the Black Sea since water temperature of the Black Sea has remained at a level that can maintain the vital activities of sea bream in the last 10 years.

According to our research, there are only three Turkey addressed published papers relating to the growth performance of sea bream cultured in the Black Sea (Şahin et al. [17]; Şahin et al. [18]; Baki [19]). No studies were available about the vitamin and mineral matter contents of *Sparus aurata* cultured in the Black Sea region comparing with the other wild and cultured fish species In this context, the aim of the study was to characterize the seasonal variation of vitamins [A (retinol), D3 (cholecalciferol), and E (alfa-tocopherol)] levels and Se, P, Zn, Ca, Na, K, Mg, and Fe trace elements contents in sea bream cultured in net cages in the Central Black Sea Region.

Materials and Methods

The research was carried out in the open sea cage system of a commercial company located in Samsun province (Town Yakakent) in Central Black Sea Region of Turkey. Thirty fish were sampled monthly from July 2015 to October 2016 by random sampling method from the cages and seasonally grouped for analyzing vitamin and mineral matter (Table 1).

Extruder feeds containing 45–55% protein and 14–20% lipid with sizes between 1 and 6 mm produced by a commercial feed company (Black Sea Feed) were used. Vitamins and mineral matter contents of feed were given in Table 2.

Water temperature was measured daily and oxygen, salinity, and pH were measured three times a month using the YSI multi-parameter device.

Fish meat and feed samples were stored in a deep freezer (WiseCryo/WUF-D500-80 °C) until analysis, and transport of samples to the laboratory was provided by cold chain conditions.

Table 1 The seasonal average length and weight of fish

Seasons	Weight (g)	Length (cm)
Autumn	38.65 ± 20.19	11.04 ± 2.50
Winter	89.30 ± 0.68	17.65 ± 0.16
Spring	122.87 ± 19.43	19.25 ± 0.97
Summer	380.99 ± 36.89	27.25 ± 1.48

Vitamins A, D_3, and E of analyses were performed by chromatographic HPLC method; mineral matter analyses (Se, P, Zn, Ca, Na, K, Mg, and Fe) were performed by wet digesting of the samples with HNO3/HCO4 [20] using IPC-OES (inductively coupled plasma/optical emission spectrometer) in a private accredited laboratory (DÜZEN NORWEST, Environment, Food and Veterinary Health Services Education Consultancy Trade Inc.)

The homogenized samples were weighed and saponified. For saponification of vitamins, ethanolic potassium hydroxide (KOH), sodium chloride (NaCl), methanolic ascorbic acid, and butylated hydroxy tolüene (BHT) were added to approximately 10 g of sample and saponified at 80 °C for 45 min. Saponified samples were then extracted with 70 ml of diethyl ether and the upper phase was transferred to a separating funnel. The ether extract in the separation funnel was washed sequentially with KOH, ethanol, and distilled water. After evaporation of diethyl ether in a balloon by a vacuum evaporator, the residue was dissolved in methanol and injected. For vitamin D, the residue was dissolved in methylene chloride-IPA solution and eluted with acetonitrile. The eluate was evaporated under nitrogen gas in a water bath and after drying the residue was dissolved in 1 mL of methanol and injected.

The quantifications of vitamin A and E were done by HPLC with the following conditions: HPLC column, ACE 5 C18 25 cm; mobile phase,100% methanol; UV detector wavelength change program, 325 nm (for vitamin A) and 292 nm (for vitamin E). The quantification of vitamin D was done by HPLC with the following conditions: HPLC column, ACE 5 C18 25 cm; mobile phase, 100% methanol; injection amount, 100 μL; mobile phase velocity, 1.5 mL; column temperature, 25 °C; and UV detector wavelength, 265 nm.

Mineral matter analyses (Se, P, Zn, Ca, Na, K, Mg, and Fe) were performed by wet digesting of the samples with HNO3/HCO4. 0.5 g of sample from the homogenous sample was placed in the dishes of the microwave digesting device. Concentrated nitric acid (HNO_3) and hydrogen peroxide (H_2O_2) were added to the sample and disintegrated in the appropriate microwave program. The containers were fulfilled up to 25 mL with ultrapure water and read on the ICP-OES (inductively coupled plasma/optical emission spectrometer) [20].

Table 2 Vitamins and minerals matter contents of feed used in the study (mean±SE)

Feed Size Seasons	1 mm Autumn	1.5 mm Winter	2 mm Spring	3–4 mm Summer	5–6 mm
Vitamin compositions (mg/kg)					
Vitamin A	1.60 ± 0.07^{a}	1.20 ± 0.14^{a}	1.10 ± 0.07^{a}	1.50 ± 0.14^{a}	1.75 ± 0.04^{a}
Vitamin E	160.50 ± 0.35^{c}	69.50 ± 3.89^{a}	76.50 ± 2.47^{a}	101.50 ± 1.77^{b}	99.00 ± 2.83^{b}
Minerals contents (mg/kg)					
Ca	$25{,}935.00 \pm 357.10^{b}$	$31{,}305.00 \pm 1149.10^{c}$	$34{,}185.00 \pm 647.00^{c}$	$16{,}870.00 \pm 134.40^{a}$	$21{,}825.00 \pm 24.80^{b}$
Fe	237.70 ± 2.30^{a}	303.60 ± 1.70^{b}	308.95 ± 5.80^{b}	651.60 ± 3.96^{d}	349.00 ± 0.28^{c}
K	4723.50 ± 77.43^{a}	5771.50 ± 8.84^{b}	5993.00 ± 61.52^{bc}	6656.00 ± 79.55^{d}	6428.00 ± 2.12^{cd}
Mg	1701.50 ± 33.59^{a}	1668.00 ± 0.71^{a}	1734.00 ± 2.12^{a}	1621.00 ± 17.68^{a}	1724.00 ± 44.90^{a}
Na	641.10 ± 14.85^{ab}	647.15 ± 2.23^{ab}	686.80 ± 0.71^{b}	680.15 ± 2.51^{ab}	623.00 ± 6.61^{a}
P	$17{,}580.00 \pm 148.49^{b}$	$18{,}630.00 \pm 381.84^{b}$	$20{,}510.00 \pm 120.21^{c}$	$13{,}285.00 \pm 102.53^{a}$	$12{,}860.00 \pm 197.99^{a}$
Zn	124.15 ± 0.81^{b}	82.88 ± 0.59^{a}	87.47 ± 0.04^{a}	165.80 ± 3.46^{c}	131.50 ± 1.70^{b}
Se	1.79 ± 0.03^{c}	1.74 ± 0.01^{bc}	2.07 ± 0.02^{d}	1.47 ± 0.04^{a}	1.57 ± 0.02^{ab}
Ca/P ratio	1.48 ± 0.03^{ab}	1.68 ± 0.10^{b}	1.67 ± 0.00^{b}	1.27 ± 0.00^{a}	1.70 ± 0.02^{b}

Values in rows marked with different letters are significantly different ($p < 0.05$)

Raw material and origins: fish meal (Agros, Monaco-France), fish oil (Monaco-France), soybean meal (obtained from genetically modified soybean) [ACS-GM005-3]:[MON-89788-1(MON89788)]:[MON-04032-6], ABD), corn gluten meal (Cargill, Bursa-Turkey), wheat flour (Farin Chemical-China), linseed oil, monocalcium phosphate. Additives: Vitamins vitamin A 15.625 IU/kg, vitamin $D_3$3126 IU/kg, and vitamin E 275 mg/kg. Trace elements: zinc oxide (ZnO) 150 mg/kg, cobalt carbonate ($CoCO_3$) 4.5 mg/kg (according to the manufacturer feed label)

All analyses results were presented as mean values±SE. Statistical analysis was done by using the IBM SPSS 21 statistical package program. The normality and equality of variance of the data were analyzed by Shapiro-Wilk's normality and Levene's tests, respectively. The differences between the results were tested by one-way analysis of variance (ANOVA). The Tukey test statistic was used for comparisons since the equality of the samples. The relationships between the values were tested by regression analysis.

Result and Discussion

Environmental Parameters

During the study, water temperatures were the lowest in February (2016) (9.09 ± 0.03 °C) and the highest in August (2016) (26.60 ± 0.01 °C). Average seasonal O_2, salinity, and pH values were between 8.76 ± 0.34–12.33 ± 0.58 mg/l, 16.03 ± 0.00–16.46 ± 0.00‰, and 8.05 ± 0.16–9.25 ± 0.02, respectively (Table 3).

Vitamin and Mineral Matter Contents of Fish Feeds

As a result of vitamin analyses of the feeds with different sizes, vitamin A values in 1, 1.5, 2, 3–4, and 5–6 mm feeds were 1.60 ± 0.07, 1.20 ± 0.14, 1.10 ± 0.07, 1.50 ± 0.14, and 1.75 ± 0.04 mg/kg, respectively ($p > 0.05$). On the other hand, vitamin E values in 1, 1.5, 2, 3–4, and 5–6 mm feeds were 160.50 ± 0.35, 69.50 ± 3.89, 76.50 ± 2.47, 101.50 ± 1.77, and 99.00 ± 2.83 mg/kg, ($p < 0.05$).

Mineral matter contents values of feeds with different sizes were Ca between 16,870.00 ± 134.35–34,185.00 ± 647.00, Fe between 237.70 ± 2.33–651.60 ± 3.96, K between 4723.50 ± 77.43–6656.00 ± 79.55, Mg between 1621.00 ± 17.68–1734.00 ± 2.12, Na between 623.00 ± 6.61–686.80 ± 0.71, P between 12,860.00 ± 197.99–20,510.00 ± 120.21, Zn between 82.88 ± 0.59–165.80 ± 3.46, and Se between 1.470.04 and 2.07 ± 0.02 mg/kg, respectively ($p < 0.05$).

According to the feed label where the biochemical composition of the feeds were indicated, all feeds contained the same amount of 15.625 IU/kg of vitamin A, 3126 IU/kg of D_3, 275 mg/kg of vitamin E, 150 mg/kg of ZnO, and 4.5 mg/kg $CoCO_3$ (Table 2).

Serra et al. [21] reported that the amounts of additive ingredients in fish feeds could affect fish weights and vitamin and mineral matter contents in fish meat; therefore, these amounts should vary according to fish size. In the present

Table 3 Seasonal average temperature, pH, salinity and oxygen values

Seasons	Temperature (°C)	pH	Salinity (‰)	O_2 (mg/l)
Autumn	22.93 ± 1.13	8.74 ± 0.06	16.18 ± 0.04	8.76 ± 0.34
Winter	11.82 ± 1.24	8.32 ± 0.09	16.39 ± 0.06	12.02 ± 0.93
Spring	14.34 ± 2.34	9.05 ± 0.08	16.22 ± 0.06	12.33 ± 0.58
Summer	26.27 ± 0.44	9.15 ± 0.02	16.19 ± 0.05	9.45 ± 0.35

study, according to the manufacturer of the used feed, the specified vitamins and minerals were added equally to all sizes of food. These differences were thought to be due to the variation in the number of raw materials in the ratio because of the vitamin and mineral matter contents of the raw materials used to meet the protein/energy needs of the fish.

Vitamin and Mineral Matter Contents of Fish Meat

Vitamins A, D_3, and E values in fish meat were 0.27 ± 0.02–0.60 ± 0.00, 0.98 ± 0.01–1.70 ± 0.00, and 3.10 ± 0.14–6.00 ± 0.21 mg/kg, respectively ($p < 0.05$) (Fig. 1).

A number of studies have been carried out on vitamins and mineral matter contents of cultured and wild fish are summarized in Tables 5 and 6. According to our research, there were no reports relating to vitamin D values in sea bream, therefore no comparison was made. In the present study, vitamin A values were higher and vitamin E values were lower than those in different studies with cultured fish (Table 5). These differences were thought to be due to the biological characteristics of fish, environmental conditions, and nutritional properties of feed. In some studies, it was noted that the vitamin values are different in wild and cultured fish [35]; the accumulation of vitamins in fish varies in tissue [36] and there is a strong relationship between the vitamin levels in the fish meat and feed [31]. However, in this study, there was no strong correlation between vitamins A and E levels in fish meat and feed ($r = -0.30$, $r = -0.22$). On the other hand, Cho [45] reported that vitamin requirements of fish vary according to feed characteristics, environmental parameters, and stress conditions. In the present study, it could be said that environmental parameters might be more effective on vitamins in the fish meat.

Mineral matter contents of fish meat were given in Table 4. In the present study, Ca and P values in fish meat were between 276.90 ± 0.99–1788.50 ± 51.27 and 2234.50 ± 15.20–2619.00 ± 7.07 mg/kg, respectively, and seasonal differences were observed ($p < 0.05$). Ca values in this study were higher than the values in the study of Özden and Erkan [24] and lower than that of Pleadin et al. [22] and Erkan and Özden [26]; whereas, P values were higher than that of Pleadin et al. [22] and lower than that of Erkan and Özden [26] done on cultured sea bream (Table 5).

It was emphasized that Ca and P balance in fish is very important as in many vertebrates, and this ratio should be 1:1 or 1/1.5 in fish feeds [44]. In our study, Ca:P ratio in the feeds ranged from 1.27 ± 0.00 to 1.70 ± 0.02, while this value in fish meat showed a variation between 0.12 ± 0.00–0.68 ± 0.00 ($p < 0.05$) and the relation between Ca and P values in fish meat was positive ($r = 0.72$). It is considered that these rates obtained in fish meat could be originated from the accumulation of Ca and P minerals in bone. In a study, Ca:P ratio was had a negative effect on Zn amount [46]. On the contrary, in the present study, it was determined that the relationship between Ca:P and Zn in fish meat was positive ($r = 0.94$). Üstdal et al. [47] reported that the amount of protein and some mineral matter contents (Ca, P, Fe, and Cu) in feeds of fish increased the utilization of Zn by the fish. The reason for this positive relationship was thought to be that Ca:P ratios in feeds were not at a level that negatively affects the amount of fish meat Zn.

K, Mg, and Na values in fish meat varied between 4244.50 ± 8.84–4761.50 ± 1.06, 251.55 ± 2.65–312.65 ± 11.42, and 56.49 ± 0.04–128.75 ± 0.18 mg/kg, respectively, and significant seasonal differences were determined ($p < 0.05$). When K, Mg, and Na values were compared with other studies, K values were higher than the wild fish, similar to the cultured fish while Mg values were similar and Na values were lower than both wild and cultured fishes (Tables 5 and 6). Comparing with the studies done on cultured sea bream (Table 5), K and Mg values were higher in this study. On the other hand, Fe values in fish meat were between 3.50 ± 0.12 and 4.47 ± 0.18 mg/kg, and no seasonally significant differences were determined ($p > 0.05$). The Fe values in this study

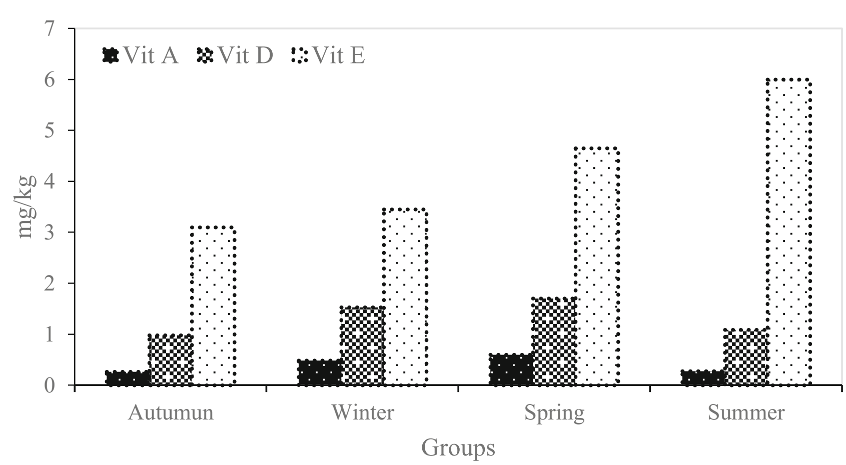

Fig. 1 Average seasonal vitamins of the fish meat

Table 4 Average seasonal minerals matter contents of the fish meat (mean ± SE)

Minerals Contents	Season			
	Autumn	Winter	Spring	Summer
Ca (mg/kg)	1788.50 ± 51.27^{c}	504.45 ± 2.02^{b}	276.90 ± 0.99^{a}	317.40 ± 2.55^{ab}
Fe (mg/kg)	4.47 ± 0.18^{a}	3.90 ± 0.16^{a}	3.50 ± 0.12^{a}	3.90 ± 0.06^{a}
K (mg/kg)	4563.00 ± 14.85^{c}	4475.50 ± 2.47^{b}	4244.50 ± 8.84^{a}	4761.50 ± 1.06^{d}
Mg (mg/kg)	312.65 ± 11.42^{c}	251.55 ± 2.65^{a}	261.75 ± 1.10^{ab}	307.70 ± 0.64^{bc}
Na (mg/kg)	128.75 ± 0.18^{d}	72.16 ± 0.32^{b}	77.04 ± 0.01^{c}	56.49 ± 0.04^{a}
P (mg/kg)	2619.00 ± 7.07^{b}	2267.50 ± 3.18^{a}	2234.50 ± 15.20^{a}	2501.50 ± 51.27^{b}
Zn (mg/kg)	15.30 ± 0.22^{d}	10.36 ± 0.24^{c}	7.20 ± 0.03^{b}	5.62 ± 0.10^{a}
Se (mg/kg)	0.38 ± 0.01^{a}	0.30 ± 0.00 ^{a}	0.36 ± 0.00 ^{a}	0.37 ± 0.03^{a}
Ca/P ratio	0.68 ± 0.02^{c}	0.22 ± 0.00^{b}	0.12 ± 0.08^{a}	0.13 ± 0.00^{a}

Values in rows marked with different letters are significantly different ($p < 0.05$)

were higher than marine wild fish (Table 6) and less than those of cultured fish (Table 5). On the other hand, Fe values obtained in this study were lower than wild sea bream (Table 6) and higher than some cultured sea bream (Table 5).

Zn values showing significant seasonal differences in fish meat ($p < 0.05$) were the highest (15.30 ± 0.22 mg/kg) during the autumn and the lowest (5.62 ± 0.10 mg/kg) ($p < 0.05$) during the summer in this study. Zn values obtained in this study were higher than wild (Table 6) and some cultured sea bream (Table 5). It was reported that the amount of Fe taken by feed decreases the amount of Zn in the body, and the decrease in animal and increase in vegetable protein sources in the diet increases Zn value and decreases Fe value [46]. However, there was a strong relationship between Fe and Zn values in fish meat in this study ($r = 0.71$).

In the study, it was determined that Se values in fish meat varied between 0.30 ± 0.01 and 0.38 ± 0.01 mg/kg and there were no significant seasonal differences ($p > 0.05$). Se values were lower than the values determined in the wild fish and higher than the studies done with cultured fishes (Tables 5 and 6). It was reported that there is a linear relationship between vitamin E and Se in fish [48], and in some fish species, vitamin E value was decreased in the absence of Se [49, 50]. However, in the present study, the relationship between vitamin E and Se values in fish meat was not as strong as expected ($r = 0.20$).

Watanabe et al. [51] reported that the amounts of Fe, Zn, and Se should be 30–170, 15–40, and 0.15–0.50 mg/kg in feed for fish. On the other hand, Cho [45] reported that it may be difficult to determine mineral matter requirements of fish because fish takes their mineral matter needs in their bodies not only from feed but also from the gill or osmoregulation. It was noted that since the concentrations of mineral matter in fish meat and in the diet vary according to the size and life cycle of fish, fish feeds should be prepared to take these factors into consideration [27].

In the study, the highest mineral matter contents were in 3–4 mm of feed given in the spring, the highest vitamin A was in 5–6 mm of feed corresponding to the summer, and the highest vitamin E was in 5–6 mm of feed given in the autumn. In fish meat, vitamins A and D_3 were increased in the spring, while vitamin E was increased in the summer. On the other hand, among the mineral matters, K and Mg values were increased in the summer and the others were increased in autumn. Siemianowska et al. [38] indicated that Ca, Na, K, and Fe values were higher in the spring and Mg, Zn, and P values were higher in the autumn in rainbow trout meat. They also stated that the culture conditions of fish significantly influenced the amounts of macro and micro elements of fish meat.

Studies showed that cultured and marine fish contain more vitamins and minerals than wild and freshwater fish, respectively. Minerals and vitamin contents of fish are affected by biological differences, origin of fish as well as seasons, nutrient factors, environmental conditions, aquaculture method, and feed sources [29], and accumulation of mineral matters and vitamins in different tissues and organs is distinct [28, 32].

Table 7 compares the daily amounts of nutrients required for adult determined by the World Health Organization and the values determined in this study. In the present study, it was determined that vitamin A and D_3 and Zn, Se, K, and Na values are equal to the amounts that people should take daily as stated in The National Academy of Sciences [52]. Larsen et al. [54] reported that fatty fish were a vitamin D source and Se, I, Zn, Mg, and Ca values were higher than in the terrestrial animal. Özden and Erkan [24] indicated that sea bass, sea bream, and common dentex (*Dentex dentex*) in the Aegean Sea are rich in mineral matters, especially in terms of K, Mg, P, and Se.

As a result of the regression analyses between the feed and the fish meat, while there was a weak relationship between vitamin A and E values and some mineral matters (K, Mg, Na, and P), the negative relationship was determined in terms of

Table 5 Some reported studies on vitamins and mineral matter contents in cultured fish (mg/kg)

Species	Vitamins		Minerals								Reference
	A	E	Ca	Fe	K	Mg	Na	P	Zn	Se	
Sparus aurata	0.27–0.60	3.10–6.00	180–1790	3.50–4.47	4240–4760	250–310	56–130	2230–2620	5.62–15.30	0.30–0.36	Present study
			540				968	2180			Pleadin et al. [22]
	0.3										Kaba et al. [23]
			195.2	224.7	3911.4	219.4	291.14	3507.38	1.08	0.24	Özden and Erkan [24]
				3.1–5.5					3.4–5.0		Yıldız [25]
			636	225	3938	222	289	3560	1.08	0.23	Erkan and Özden [26]
				5.4–10					16.0–34.0		Carpene et al. [27]
				1.3–14					3.6–7.5		Carpene et al. [28]
									20.10–28.20		Serra et al. [21]
Salmo trutta macrostigma				8.2–11.3		365.9–380.6			24.9–27.6		Zotos and Vouzanidou [29]
Salmo salar	1.5	36	90	30	3630	270	590	2400	3.4	0.24	Tacon and Metian [5]
Dicentrarchus labrax			729				706	2214			Pleadin et al. [22]
	1	23									Baki et al. [30]
				25.3–28.8		297.4–348.1			20.3–24.2		Zotos and Vouzanidou [29]
				3.6–4.3					3.6–5.1		Yıldız [25]
			616.5	25.8	4601.1	325.8	775.3	3749.8	2.9	0.3	Özden and Erkan [24]
			192	24.7	4597	326	773	3736	2.8	0.3	Erkan and Özden [26]
		98–302									Gatta et al. [31]
Pagellus bogaraveo		4.4–5.1	200–600	1.8–3.7		300			3.4–3.5	1.1–1.4	Alvarez et al. [32]
Argyrosomus regius			112	5.83	4396	284	552		5.32	0.27	Costa et al. [33] 2013
			460–610	11.34–25.30	1874–1982				14.53–21.83	0.94–2.30	Chaguri et al. [34]
Dentex dentex			1300				465	2740			Pleadin et al. [22]
		7.4									Rigos et al. [35]
			338.1	56.7	4962.2	332.3	497.7	3519.4	4.9	0.3	Özden and Erkan [24]
Scophtalmus maximus			656				1212	1811			Pleadin et al. [22]
		1.2–18.6									Stephan et al. [36]
Cyprinus carpio			382.7	6.5	3402.4	301.6	655.6	2248.6	8.3		Cieslik et al. [37]
Oncorhynchus mykkis			454.9	3.8	3750.4	284.4	329.5	2595.2	4.5		Cieslik et al. [37]
			300.4–517.4	3.0–9.4	4261.2–4615.4	306.9–338.1	464.0–718.2	2485.7–2823.6	4.5–6.9		Sieminawowska et al. [38]
			632	2.1	3060	409	455	3378.8	9.7		Gökoğlu et al. [39]
Esox lucius			556.2	3.5	2352.1	209.3	381.3	1884.7	4.4		Cieslik et al. [37]
						125.7–143.1					Brucka-Jastrzebska- Kawczuga [40]
Acipenser baeri						46.7–89.7					Brucka-Jastrzebska- Kawczuga [40]

Table 6 Some reported studies on vitamins and mineral matter contents in wild fish (mg/kg)

Species	Vitamins		Minerals								Reference
	A	E	Ca	Fe	K	Mg	Na	P	Zn	Se	
Sparus aurata	0.27	9.76									Kaba et al. [23]
				3.2					3.1		Yıldız, [25]
				1.3–20					5–10.4		Carpene et al. [28]
Oncorhynchus mykiss			127	4.2	4121	340	255	198	5.5		Celik et al. [41]
Salmo salar	0.9		120	8	4900	290	440	2000	6	3.65	Tacon and Metian [5]
Pagellus bogaraveo		7.3–9.2	400–700	1.4–1.9		0.3–0.4			2.6–3.6	0.7–0.8	Alvarez et al. [32]
Dentex dentex		3.5									Rigos et al. [35]
Dicentrarchus labrax	1	19									Baki et al. [30]
				3.1					3.1		Yıldız [25]
Sander lucioperca		9			3547	374	665		13		Özyurt et al. [42]
Cyprinus carpio	2.3.5	5			3581	342	613		13		Özyurt et al. [42]
Silurus glanis	0.63	8			3059	271	1301		13		Özyurt et al. [42]
Clarias gariepinus	1.81	3	40.1	12.0	1817	184	308		3.5		Ersoy and Özeren [43]
Engraulis encrasicholus	1.5	5	1470	33	3830	410	1040	1740	17	3.65	Tacon and Metian [5]
Solea vulgaris vulgaris			801	8	2860	353	1600	5190	6		Martinez-Valverde et al. [44]

Fe values ($r = -0.75$). The US National Health Organization stated that there is a linear relationship between vitamin A and Fe values [55]. In this study, the relationship between vitamin A and Fe values was not strong ($r = -0.59$). It was reported that Vitamin A and Fe values in animal muscle tissues are related to balanced nutritional conditions, and vitamin A deficiency may affect Fe storage within the body [56]. It was thought that the reason for the difference in terms of the relationship between Fe and Vitamin A in this study from the aforementioned study could be caused by the used diet and the balance of raw material (animal/vegetable) in the ration.

Na, Zn, and Ca values in fish meat were negatively correlated with fish weights ($r = -0.73$, $r = -0.79$, $r = -0.97$) in the present study. It was also determined that as fish weights increased, the value of vitamin E in fish meat increased ($r = 0.95$).

It is known that environmental parameters are very effective on fish metabolism. The study showed that while there was a negative relationship between vitamins A and D_3 and water temperature ($r = -0.88$ $r = -0.88$), positive relationship between K, Mg, P, and Se values and water temperature ($r = 0.79$, $r = 0.96$, $r = 0.87$, and $r = 0.78$) were determined. There

Table 7 Meeting the daily recommended allowances for selected vitamins and minerals by a 100 g portion of seabream

Vitamin and minerals	Study results (mg/kg)	RDA/EU[1]	Meeting the norm (%)	RDA/TR[2]	Meeting the norm (%)
Vitamin A	0.27–0.60	800 μg	7.5	700–900 μg	6.7
Vitamin D_3	0.98–1.70	5 μg	3.4	10 μg	7
Vitamin E	3.10–6.00	12 mg	2	11–15 mg	4
Ca	180–1790	800 mg	22.4	1000–1300 mg	13.8
Fe	3.50–4.47	14 mg	3.20	10–18 mg	2.48
K	4240–4760	2000 mg	23.8	–	–
Mg	250–310	375 mg	8.3	240–420 mg	7.38
Na	56–130	–	–	–	–
P	2230–2620	700 mg	37.4	700–1250 mg	20.96
Zn	5.62–15.30	10 mg	15.3	10–11 mg	15
Se	0.30–0.36	55 μg	6.5	40–45 μg	6.5

[1] RDA Commission Directive 2008/100/EC of 28 October 2008, [52]

[2] RDA Republic of Turkey Ministry of Health General Directorate of Primary Health Care Food Safety Department Community Nutrition Division [53]

was also a negative relationship between salinity and Fe and P values in fish meat ($r = -0.89$, $r = -0.76$) and positive relationship with K value ($r = 0.79$).

As a result, the sea bream cultured in the Central Black Sea region is as nutritive as with the other fish species and its wild and cultured forms in different areas and rich in terms of vitamin A and mineral matters like Zn, Se, K, and Na. Cultivation of this species is very promising for Turkish aquaculture sector which is in search of alternative fish species for Black Sea conditions.

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