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Seasonal Variations in Yield, Fatty Acids, Amino Acids and Proximate Compositions of Sea Urchin (*Paracentrotus lividus*) Roe

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ABSTRACT

Sea urchin (*Paracentrotus lividus*) roes are popular delicacy to human. In this study, seasonal variations in the yield, fatty acid, amino acid and proximate compositions of sea urchin roe were studied. The average yield was 5.45 ± 2.21%. Protein, crude fat, moisture, ash and carbohydrate contents were 12.03 ± 1.26%, 3.05 ± 0.50%, 79.87 ± 1.43%, 2.25 ± 0.24%, and 2.80 ± 2.41%, respectively. The fatty acids of C16:0, C20:5 n3 and C22:2 n6 were the important fatty acids, whereas the major amino acids were glutamic acid (non-essential, NE), glycine (NE), aspartic acid (NE), lysine (essential, E) and arginine (NE). The E/NE ratio was 0.58 ± 0.01 and fatty acids were rich in PUFA. It was concluded that sea urchin roes are rich sources of unsaturated fatty acids, proteins and amino acids, which are the essential components of human nutrition.

Key words: sea urchin roe, chemical composition, amino acids, fatty acids

INTRODUCTION

Paracentrotus lividus is a common species in Turkish coasts. It generally exists on rocks, corals and shells. This species lives in Mediterranean, Aegean and Marmara seas[1-3]. Its gonads are appreciated for consumption[4] in Far-Eastern countries, particularly Japan where "uni" is regarded as an expensive delicacy[5,6].

In Japan, catching rates of sea urchin were reported as 24,000 metric tones in 1981 and 14,000 metric tonnes in 1991[7]. Japan also imports sea urchin from the United States, Russia, Canada, North and South Korea, Chile and China[7]. It was reported that, sea urchins have been over fished to meet the great demand of this species in Japan, France, Ireland, Canadian Maritime Provinces, Chile, and Northeast of the United States[9]. Recently, there is a great interest of the aquaculture of sea urchins due to popular demands and decreasing of the sources[10-12]. As the result, estimation of potential catching areas has also taken importance in recent years[13].

In this study, the yield, proximate composition, fatty acids, and amino acids of sea urchin (*Paracentrotus lividus*) roe were studied seasonally for a year to estimate its nutritional and chemical properties.

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MATERIALS AND METHODS

I. *Materials*

Materials were collected in a 2-month period from Marmara Sea, Turkey. Sampling was carried out in February, April, June, August, October, and December 2005. The average weights of the samples were 37.09 ± 8.79 g, 30.68 ± 8.57 g, 32.27 ± 6.38 g, 26.92 ± 6.17 g, 20.96 ± 6.18 g, and 21.48 ± 4.96 g, respectively. The lengths of the samples were measured in February (4.50 ± 0.61cm), April (4.48 ± 0.59 cm), in June (4.47 ± 0.37 cm), August (4.23 ± 0.42 cm), October (4.06 ± 0.43 cm) and December (3.72 ± 0.34 cm). Ten kilograms of sea urchins were used for each sampling. Samples were placed in styrofoam boxes with ice and transported to Istanbul University, Faculty of Fisheries, Food Processing Laboratory within 6 hr after catching. The shells were broken and gonads removed. Moisture, ash, protein, crude fat, amino acid and fatty acid analyses were carried out in five replicates. Carbohydrate and energy values were calculated.

II. *Yield of Sea Urchins Roe*

Forty sea urchins and their gonads were weighed

(Libror AEG 220, Shimadzu, Japan). The weight of gonads were divided by the weight of sea urchins and multiplied by 100 for the yield estimation.

III. *Protein Analysis*

Crude protein was determined by the Kjeldahl method(14). The sample was heated to 420°C for 20 min. with 98% H_2SO_4 and catalyst using DK6 Heating digester (Velp Scientifica, Italy); then treated with 33% NaOH and 4% boric acid by Velp UDK 140 distillation unit (Velp Scientifica, Italy). The amount of nitrogen was estimated after titration with 0.2 N HCl. It was multiplied by the coefficient 6.25. All chemical reagents were purchased from Merck, Darmstadt, Germany.

IV. *Crude Fat Analysis*

Samples were mixed with petroleum ether (Aldrich, Taufkirchen, Germany) and acetone (Merck, Darmstadt, Germany) in a tube. This mixture was centrifuged and upper layer was taken into a flask. Solvents were evaporated at 60°C (Rotavapor 2-3000, Buchi Labortechnic, Switzerland). Flask was kept in 105°C for 3 hr (FN 500, Nüve, Turkey) and then weighed(15).

V. *Moisture Determination*

Moisture content was determined by drying the sample at 105°C (FN500, Nüve, Turkey) to constant weight(16). The weight difference between before and after drying was multiplied by 100 and divided by the initial weight of the sample.

VI. *Ash Determination*

Homogenized sample (5 g) was weighed in a well dried porcelain basin and subjected to a low bunsen flame. Samples were subjected to 550-570°C (MF100, Nüve, Turkey) and cooled in a desiccator. Amount of ash was calculated considering the difference of weight after and before this procedure(17).

VII. *Carbohydrate and Energy Values*

Carbohydrate content was calculated by the difference between 100 and the sum of the crude protein, crude fat, moisture and ash. Energy values of the samples were also calculated and expressed as Kcal/100g. The coefficients were 5.65 for protein, 9.50 for fat and 3.90 for carbohydrates(18).

VIII. *Fatty Acid Composition*

The IUPAC method(19) was used to determine fatty acid composition and results were expressed as area percent (%). Sample (0.150 g) was mixed with 5 mL, 0.5 N methanolic NaOH (106498 Merck, Darmstadt, Germany) in a flask equipped with a glass cooler and boiled for 15 min in a water bath. This mixture was added to 5 mL of BF_3 (801663 Merck, Darmstadt, Germany) and boiled for 5 min. After adding 2-5 mL of heptane (104379 Merck, Darmstadt, Germany), the mixture was boiled again for 1 min. Upper layer was mixed with crystal anhydrous Na_2SO_4 (1006649 Merck, Darmstadt, Germany) and injected to Thermoquest Trace GC (Milan, Italy).

Specifications of the apparatus have been given below:

SP-2330 fused silica capillary column 30 m, 0.25 mm ID, 0.20 μm film.

Oven: 120°C, 2 min; 220°C, 8 min.

Detector: FID 260°C

Injector: 240°C

Air: 350 mL/min

H2: 35 mL/min

Make up: 30 mL/min (N_2)

Range: 1

Carrier: 0.5 mL/min

Split ratio: 1/150

Sample injection: 0.5 μL

Standard: sigma (Code: 189-19) lipid standard (Fatty Acid Methyl Ester mixtures)

IX. *Amino Acid Composition*

For estimation of amino acid composition, a sample was prepared prior to hydrolysis. Performic acid oxidation was performed to oxidize cystine and methionine to cysteic acid and methionine sulfone. Sodium metabisulfite (Aldrich, Taufkirchen, Germany) was added to decompose performic acid. Amino acids were hydrolyzed by 6M HCl (Merck, Darmstadt, Germany). The hydrolysates were neutralized with sodium citrate buffer. The pH was adjusted to 2.20. And the amino acids were separated by high performance liquid chromatography (HPLC). Aglient 1100 HPLC (Palo Alto, CA, USA) equipped with Aglient Zorbax SB-C18 4.6 × 75 mm column and Aglient 1100 G1314A UV detector (Palo Alto, CA, USA) was used. Wave length was 338 nm for primary amino acids and 262 nm for secondary amino acid (proline)(20).

X. *Statistical Analysis*

Statistical differences were studied on the probability $p < 0.05$ and ANOVA was performed to compare the means(21).

RESULTS AND DISCUSSION

In this study, sea urchins were analyzed every 2 months for a year and their average weight and length were found to be 28.23 ± 9.26 g and 4.24 ± 0.56 cm, respectively. The yield of sea urchin roe was highest in April (9.69 ± 3.38%) and lowest in February (3.54 ± 1.73%). These differences were significant according to statistical analysis ($p < 0.05$). Sea urchin reproduces throughout whole year(22,23). However it was also mentioned that the reproduction increases in summer[22]. In another study, it was reported that the reproduction period of sea urchin is between late spring and summer[24]. In this study it was determined that reproduction of sea urchins increase in spring and summer, similar to the previous studies and it is possible to find sea urchin roe throughout the whole year. Protein, crude fat, moisture, ash and carbohydrate contents of sea urchin roe were also studied and their mean values were estimated as 12.03 ± 1.26%, 3.05 ± 0.50%, 79.87 ± 1.43%, 2.25 ± 0.24%, and 2.80 ± 2.41%, respectively. The highest levels of protein and moisture contents were in June (14.30 ± 0.25% and 81.15 ± 0.26%, respectively), whereas the lowest levels were in December (10.82 ± 0.31% and 77.97 ± 0.80%, respectively). These differences were significant ($p < 0.05$) according to statistical analysis. However, crude fat content of gonads was not significantly different during the year ($p > 0.05$). Amount of ash was higher ($p < 0.05$) at the second half of the year. The mean energy value was 107.81 ± 4.98 Kcal/100 g and carbohydrate content was 2.80 ± 2.41%. The proximate composition, energy and yield of sea urchin roe are presented in Table 1.

There are several studies on the chemical composition of fish roe. The protein, crude fat, moisture and mineral contents of caviar were reported as 26.1%, 15.5%, 47.1%, and 6.73%, respectively[25]. Various species of fish were studied and it was reported that their roes contain lipids between 10.66% and 2.86%[26]. The chemical composition of mullet roe was also studied[27]. Its protein content was estimated as 25.52%, and the crude fat as 9.89%. In the other study, protein, fat, moisture and ash contents of channel catfish roe were determined as 24.6%, 8.0%, 64.5%, and 2.4%, respectively[28]. These literatures show that sea urchin roe contains lower amounts of protein and fat than many fish roes.

Chemical compositions of the various species of sea urchin were also studied. Sea urchins were harvested (*Paracentrotus lividus*) in Galicia (NW Spain) during March and the moisture content of their gonads were reported as 73.0%[13]. The protein, fat, moisture and ash contents of sea urchins (*Strongylocentrotus droebachiensis*) were reported as 7.4%, 4.7%, 74.7% and 2.2%, respectively[29]. Their protein content was lower, but the amount of fat was higher than that of our samples. In another study, chemical composition of sea urchin roe was studied between November and February[5]. It was reported that the protein (16.3%) and fat (8.4%) contents determined were higher than those of our study. These differences are related with the sea urchins' diet which depends on the abundance of algae; therefore catching area and diet of sea urchin affects its proximate composition[29,30]. According to these literatures, it is clear that the differences between species, diet and populations affect the chemical composition of sea urchin roe.

Fatty acid composition of sea urchin roe was measured every two months for one year (Table 2). The fatty acids C16:0 and C20:5 n3 were predominant in the roe of *Paracentrotus lividus* in this study. This result is very similar to those in the literature[13,29]. In this study, the amount of C14:0 was also significantly similar to the former literatures and it was also determined that the other important fatty acid is C22:2 n6 acid for sea urchin roe. The average n3/n6 ratio was determined as 1.55 ± 0.41 and total amounts of unsaturated fatty acids [MUFA (Mono Unsaturated Fatty Acids) and PUFA (Poly Unsaturated Fatty Acids)] were significantly higher ($p < 0.05$) than saturated fatty acids [SFA (Saturated Fatty Acids)]. PUFA content of the samples was also significantly higher ($p < 0.05$) than SFA and MUFA contents.

C10:0 and C12:0 fatty acids were only found in August and October. Similarly, C15:1 was seen in April and October. C22:0 was determined in April, June and August. All of these fatty acids were in trace amounts (lower than 1%). C20:4 n6 appeared only in October (3.45 ± 0.08%) and December (4.32 ± 0.05%). These fatty

Table 1. Proximate composition, energy and yield of sea urchin roe

	February	April	June	August	October	December	Mean
Protein (%)	11.45 ± 0.50^{a}	11.14 ± 0.53^{a}	14.30 ± 0.25^{b}	12.51 ± 0.72^{c}	11.95 ± 0.56^{a}	10.82 ± 0.31^{a}	12.03 ± 1.26
Crude fat (%)	2.41 ± 0.44^{a}	3.23 ± 0.23^{a}	2.40 ± 0.51^{a}	3.49 ± 0.55^{a}	3.35 ± 0.54^{a}	3.39 ± 0.50^{a}	3.05 ± 0.50
Moisture (%)	79.81 ± 0.38^{a}	78.31 ± 1.83^{ac}	81.15 ± 0.26^{b}	81.01 ± 0.99^{b}	80.99 ± 0.95^{b}	77.97 ± 0.80^{c}	79.87 ± 1.43
Ash (%)	2.07 ± 0.26^{a}	2.02 ± 0.09^{a}	2.03 ± 0.35^{a}	2.33 ± 0.34^{ab}	2.52 ± 0.34^{b}	2.53 ± 0.25^{b}	2.25 ± 0.24
Carbohydrate (%)	4.26 ± 0.11^{a}	5.30 ± 0.18^{b}	0.12 ± 0.07^{c}	0.66 ± 0.12^{d}	1.19 ± 0.16^{e}	5.29 ± 0.17^{b}	2.80 ± 2.41
Energy (Kcal/100g)	104.19 ± 2.5^{a}	114.29 ± 2.7^{b}	104.06 ± 3.1^{a}	106.37 ± 3.4^{c}	103.98 ± 4.4^{a}	113.97 ± 2.8^{b}	107.81 ± 4.98
Yield (%)	3.54 ± 1.73^{a}	9.69 ± 3.38^{b}	5.11 ± 1.33^{c}	5.35 ± 1.67^{c}	5.11 ± 1.31^{c}	3.88 ± 1.66^{a}	5.45 ± 2.21

Different letters in the same row show significant differences among samples ($p < 0.05$).

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acids are not shown in Table 2 since they were not seen in the remaining year.

Amino acids of sea urchin roe are shown in Table 3. In this study, it was determined that sea urchin roe contained aspartic acid, threonine, serine, glutamic acid, proline, glycine, alanine, cystine, valine, methionine, isoleucine, leucine, tyrosine, phenylalanine, histidine, lysine, and arginine. Tryptophan was not determined in this study. Similar results were reported in the literature[31]. Glutamic acid, aspartic acids, alanine and

Table 2. Fatty acid composition (area percent) of sea urchin roe

Fatty acids	February (%)	April (%)	June (%)	August (%)	October (%)	December (%)	Mean (%)
C14:0	3.67 ± 0.02^{a}	3.99 ± 0.00^{b}	4.17 ± 0.05^{bc}	4.35 ± 0.03^{c}	6.00 ± 0.45^{d}	7.53 ± 0.41^{e}	4.95 ± 1.50
C15:0	1.05 ± 0.00^{a}	0.79 ± 0.00^{b}	0.75 ± 0.00^{b}	0.64 ± 0.01^{c}	1.29 ± 0.10^{d}	0.77 ± 0.05^{b}	0.88 ± 0.24
C16:0	11.17 ± 0.02^{a}	9.96 ± 0.02^{b}	11.62 ± 0.12^{ac}	12.18 ± 0.02^{c}	16.45 ± 0.63^{d}	17.93 ± 0.33^{e}	13.22 ± 3.20
C17:0	0.79 ± 0.01^{a}	0.85 ± 0.07^{ac}	0.33 ± 0.01^{b}	0.35 ± 0.03^{b}	0.90 ± 0.04^{c}	0.37 ± 0.01^{b}	0.60 ± 0.27
C18:0	2.97 ± 0.06^{ad}	2.84 ± 0.01^{a}	3.16 ± 0.02^{b}	2.60 ± 0.05^{c}	2.96 ± 0.03^{d}	2.11 ± 0.00^{e}	2.77 ± 0.37
C20:0	0.57 ± 0.00^{a}	0.51 ± 0.01^{a}	0.53 ± 0.01^{a}	0.24 ± 0.20^{b}	0.44 ± 0.02^{c}	0.40 ± 0.01^{c}	0.45 ± 0.12
C21:0	1.22 ± 0.04^{a}	1.34 ± 0.01^{a}	1.08 ± 0.03^{b}	0.74 ± 0.05^{c}	2.14 ± 0.10^{d}	2.48 ± 0.10^{d}	1.50 ± 0.67
C23:0	0.62 ± 0.01^{ac}	0.79 ± 0.02^{a}	1.15 ± 0.39^{b}	0.77 ± 0.47^{a}	1.10 ± 0.09^{b}	0.51 ± 0.03^{c}	0.82 ± 0.26
C24:0	0.46 ± 0.04^{a}	0.50 ± 0.02^{ab}	0.53 ± 0.02^{b}	0.44 ± 0.006^{a}	0.16 ± 0.05^{c}	0.22 ± 0.02^{c}	0.39 ± 0.16
Total SFA	22.50	21.57	23.32	22.31	31.44	32.32	25.58 ± 4.92
C14:1	0.32 ± 0.01^{a}	0.38 ± 0.01^{ad}	0.15 ± 0.01^{b}	0.18 ± 0.00^{bc}	0.22 ± 0.02^{c}	0.41 ± 0.03^{d}	0.28 ± 0.11
C16:1	2.52 ± 0.18^{ad}	3.37 ± 0.01^{b}	1.23 ± 0.01^{c}	1.20 ± 0.01^{c}	2.06 ± 0.13^{d}	2.20 ± 0.08^{d}	2.10 ± 0.82
C17:1	0.43 ± 0.01^{a}	2.22 ± 0.04^{b}	0.23 ± 0.01^{c}	0.30 ± 0.07^{c}	1.16 ± 0.04^{d}	0.88 ± 0.01^{d}	0.87 ± 0.75
C18:1 n9t	0.49 ± 0.01^{a}	0.44 ± 0.01^{ac}	0.30 ± 0.01^{b}	0.37 ± 0.01^{c}	0.45 ± 0.01^{a}	0.36 ± 0.01^{c}	0.40 ± 0.07
C18:1 n9c	6.52 ± 0.03^{a}	5.28 ± 0.00^{b}	4.80 ± 0.04^{bd}	8.83 ± 0.05^{c}	4.67 ± 0.15^{d}	5.71 ± 0.25^{b}	5.97 ± 1.55
C20:1 n9	2.40 ± 0.01^{a}	2.22 ± 0.02^{a}	2.61 ± 0.02^{b}	2.30 ± 0.02^{a}	2.54 ± 0.12^{b}	3.16 ± 0.11^{c}	2.54 ± 0.34
C22:1 n9	1.38 ± 0.05^{a}	1.12 ± 0.01^{b}	1.63 ± 0.01^{c}	0.99 ± 0.00^{b}	1.39 ± 0.01^{a}	1.44 ± 0.12^{a}	1.33 ± 0.23
C24:1n9	0.47 ± 0.02^{ad}	0.51 ± 0.01^{a}	0.08 ± 0.01^{b}	0.15 ± 0.01^{b}	0.26 ± 0.01^{c}	0.36 ± 0.03^{d}	0.31 ± 0.17
Total MUFA	14.53	15.54	11.03	14.32	12.75	14.52	13.78 ± 1.62
C18:2 n6t	0.32 ± 0.01^{a}	0.30 ± 0.00^{ab}	0.26 ± 0.00^{bd}	0.14 ± 0.00^{c}	0.23 ± 0.00^{d}	0.32 ± 0.00^{a}	0.26 ± 0.07
C18:2 n6c	3.20 ± 0.07^{a}	1.39 ± 0.01^{b}	0.79 ± 0.00^{c}	2.32 ± 0.01^{d}	1.69 ± 0.01^{b}	2.22 ± 0.01^{d}	1.94 ± 0.84
C18:3 n6g	0.34 ± 0.01^{ac}	0.47 ± 0.02^{bc}	0.30 ± 0.04^{a}	0.57 ± 0.00^{b}	0.42 ± 0.01^{c}	0.60 ± 0.00^{b}	0.45 ± 0.12
C18:3 n3a	3.09 ± 0.05^{a}	2.08 ± 0.02^{b}	2.35 ± 0.02^{b}	5.81 ± 0.02^{c}	2.99 ± 0.04^{a}	5.06 ± 0.03^{c}	3.56 ± 1.52
C20:2 n6	2.83 ± 0.01^{ab}	2.59 ± 0.01^{a}	2.58 ± 0.01^{a}	3.12 ± 0.02^{b}	1.21 ± 0.06^{c}	1.20 ± 0.04^{c}	2.26 ± 0.84
C20:3 n3	0.70 ± 0.01^{ab}	0.57 ± 0.02^{b}	1.16 ± 0.01^{c}	1.25 ± 0.02^{c}	0.78 ± 0.03^{a}	0.97 ± 0.03^{c}	0.91 ± 0.27
C22:2 n6	9.93 ± 0.161^{a}	9.33 ± 0.03^{a}	12.35 ± 0.06^{b}	12.03 ± 0.09^{b}	5.26 ± 0.61^{c}	5.13 ± 0.02^{c}	9.00 ± 3.17
C20:5 n3	11.77 ± 0.01^{ac}	16.01 ± 0.04^{b}	16.76 ± 0.04^{b}	13.54 ± 0.07^{a}	11.12 ± 0.41^{c}	9.73 ± 0.25^{d}	13.16 ± 2.80
C22:6 n3	2.69 ± 0.02^{a}	4.19 ± 0.06^{b}	1.48 ± 0.10^{c}	1.74 ± 0.00^{c}	4.34 ± 0.43^{b}	1.78 ± 0.11^{c}	2.70 ± 1.28
Total PUFA	34.87	36.93	38.03	40.52	28.04	27.01	34.23 ± 5.52
Total n3	18.25	22.85	21.75	22.34	19.23	17.54	20.33 ± 2.27
Total n6	16.62	14.08	16.28	18.18	8.81	9.47	13.90 ± 3.92
n3/n6	1.10	1.62	1.34	1.23	2.18	1.85	1.55 ± 0.41

Different letters in the same row show significant differences among samples ($p < 0.05$).
SFA: saturated fatty acids; MUFA: mono unsaturated fatty acids; PUFA: poly unsaturated fatty acids.

Table 3. Amino acid composition of sea urchin roe

Amino acids	February	April	June	August	October	December	Mean
Essential amino acids (E) (g/100g)							
Histidine	0.26 ± 0.01^{a}	0.24 ± 0.00^{a}	0.25 ± 0.05^{a}	0.26 ± 0.02^{a}	0.31± 0.01^{b}	0.27 ± 0.01^{a}	0.27 ± 0.02
İsoleu^{c}ine	0.42 ± 0.03^{a}	0.45 ± 0.02^{a}	0.45 ± 0.04^{ab}	0.45 ± 0.01^{a}	0.49 ± 0.02^{b}	0.50 ± 0.03^{b}	0.46 ± 0.03
Leu^{c}ine	0.68 ± 0.02^{a}	0.70 ± 0.04^{a}	0.77 ± 0.02^{b}	0.78 ± 0.03^{b}	0.81 ± 0.04^{b}	0.78 ± 0.04^{b}	0.75 ± 0.05
Lysine	0.81 ± 0.02^{a}	0.77 ± 0.05^{a}	0.82 ± 0.05^{a}	0.89 ± 0.02^{b}	0.96 ± 0.03^{c}	0.86 ± 0.05^{b}	0.85 ± 0.07
Methionine	0.19 ± 0.00^{ac}	0.13 ± 0.01^{b}	0.18 ± 0.04^{a}	0.19± 0.01^{a}	0.23 ± 0.04^{c}	0.14 ± 0.01^{b}	0.18 ± 0.04
Phenylalanine	0.42 ± 0.04^{a}	0.51 ± 0.02^{b}	0.51 ± 0.02^{b}	0.50± 0.04^{b}	0.50 ± 0.05^{b}	0.56 ± 0.02^{c}	0.50 ± 0.05
Threonine	0.47 ± 0.02^{a}	0.48 ± 0.04^{a}	0.49 ± 0.03^{a}	0.50 ± 0.02^{a}	0.56 ± 0.03^{b}	0.53 ± 0.01^{b}	0.51± 0.03
Valine	0.43 ± 0.03^{a}	0.40 ± 0.01^{a}	0.49 ±0.02^{b}	0.50 ± 0.04^{b}	0.51 ± 0.00^{b}	0.44 ± 0.02^{a}	0.46 ± 0.04
Total E	3.68	3.68	3.96	4.07	4.37	4.08	3.97 ± 0.26
Nonessential amino acids (NE) (g/100g)							
Arginine	0.88 ± 0.02^{a}	0.73 ± 0.03^{b}	0.84 ± 0.02^{ad}	0.99 ± 0.04^{c}	0.85 ± 0.04^{ad}	0.81 ± 0.01^{d}	0.85 ± 0.09
Aspartic acid	0.99 ± 0.05^{a}	0.97 ± 0.04^{a}	0.99 ± 0.02^{a}	1.00 ± 0.02^{a}	1.16 ± 0.06^{b}	1.07 ± 0.06^{a}	1.03 ± 0.07
Serine	0.44 ± 0.02^{a}	0.43 ± 0.02^{a}	0.48 ± 0.01^{b}	0.52 ± 0.03^{b}	0.53 ± 0.04^{b}	0.48 ± 0.02^{b}	0.48 ± 0.04
Glutamic acid	1.49 ± 0.08^{a}	1.49 ± 0.02^{a}	1.57 ± 0.05^{a}	1.59 ± 0.09^{a}	1.76 ± 0.02^{b}	1.65 ± 0.04^{a}	1.59 ± 0.10
Proline	0.41 ± 0.01^{a}	0.40 ± 0.03^{a}	0.45 ± 0.03^{a}	0.49 ± 0.05^{b}	0.49 ± 0.03^{b}	0.45 ± 0.00^{a}	0.45 ± 0.04
Glycine	1.10 ± 0.04^{ab}	1.01 ± 0.05^{a}	1.15 ± 0.07^{b}	1.12 ± 0.05^{b}	1.30 ± 0.05^{c}	1.13 ± 0.02^{b}	1.14 ± 0.09
Alanine	0.58 ± 0.03^{a}	0.51 ± 0.05^{b}	0.59 ± 0.04^{a}	0.62 ± 0.02^{a}	0.69 ± 0.05^{c}	0.57 ± 0.04^{a}	0.59 ± 0.06
Cystine	0.24 ± 0.00^{a}	0.25 ± 0.02^{a}	0.26 ± 0.01^{a}	0.27 ± 0.01^{ab}	0.30 ± 0.02^{b}	0.27 ± 0.03^{b}	0.27 ± 0.02
Tyrosine	0.44 ± 0.02^{a}	0.48 ± 0.01^{ab}	0.49 ± 0.03^{b}	0.50 ± 0.04^{b}	0.51± 0.04^{b}	0.51 ± 0.02^{b}	0.49 ± 0.03
Total NE	6.57	6.27	6.82	7.10	7.59	6.94	6.88 ± 0.45
Total amino acid	10.25	9.95	10.78	11.17	11.96	11.02	10.86 ± 0.71
E : NE ratio	0.56	0.59	0.58	0.57	0.58	0.59	0.58 ± 0.01

Different letters in the same row show significant differences among samples ($p < 0.05$)

leucine were reported as the major amino acids of channel catfish roe(28). It was also mentioned that the most important amino acids were glutamic acid and glycine for sea urchin roe. Similarly, the major amino acids were glutamic acid (NE), glycine (NE), aspartic acid (NE) and, their contents were significantly higher ($p < 0.05$) than the other amino acids in this study. The main essential amino acids were lysine and leucine. Some sea urchins become sporadically bitter, which poses a serious problem for the fishery industry. The bitter taste of sea urchin ovaries has been thought to be due to the presence of free amino acids such as valine, leucine, and isoleucine(32). The total amount of these amino acids was 1.67 g/100 g in this study. Essential (E)/non-essential (NE) amino acid ratio was observed to be 0.58 ± 0.01 in this study. This value was presented as 0.74 in the literature and it was mentioned that, roe has a favorable E/NE ratio and it is a valuable food source of high-quality protein(5).

CONCLUSIONS

In this study it was determined that protein amount was significantly higher in the summer, while fat content did not show important fluctuations throughout the year. The values of glutamic and aspartic acids were also constant during the year but they increased in October. The other important amino acids (aspartic acid, glycine and arginine) showed little variations in different seasons. The amounts of major fatty acids C22:2 n6 and C20:5 n3 were highest in the summer. The other major fatty acid (C16:0) increased linearly from summer to winter and then decreased in late winter and spring. Yield was highest in April, almost constant between June and October and lowest in winter, but it was possible to find sea urchin roe throughout the whole year. It has been concluded that sea urchin roes from Turkish coasts are rich in chemical components and nutritive similar to findings in previous studies. Therefore, Turkish coasts might be regarded as an alternative source of sea urchin roe.

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