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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

Effect of Seasons on Fatty Acid Composition of *Laurencia obtusa* (Hudson) J.V. Lamouroux, 1813 From Sinop Coast of the Black Sea

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Abstract: The aim of this study was to determine the fatty acid profile of *Laurencia obtusa* collected from the Sinop coast. The fatty acids profile were analyzed by GC/MS and their seasonal variation was studied. Along the sampling, it was identified 36 different fatty acids in *L. obtusa*. During the research, it was determined that the most abundant fatty acid was palmitic acid with values ranging from 33.78±1.03% in autumn to 44.51±1.70% in summer. At the end of the study, it was determined that the season in which *L. obtusa* was richest in terms of PUFA and SFA contents was spring and in terms of MUFA content was autumn. In addition, in this study, it has been determined that the PUFA/SFA ratio in *L. obtusa* varied between 0.10% and 0.23% from winter to summer, and the total n-6/n-3 PUFA ratio changed between 1.14% and 2.37% from summer to autumn. It was determined that the atherogenicity index (AI) value changed between 1.75 and 1.97 from autumn to summer, and the thrombogenicity index (TI) value changed between 1.58 and 2.22 from winter to autumn. As a result of the research, it was revealed that the seasons have a significant effect on the fatty acid profile.

Keywords: Black sea, fatty acid, GC/MS, macroalgae, *Laurencia obtusa*, PUFA.

Karadeniz'in Sinop Sahilinden *Laurencia obtusa* (Hudson) J.V. Lamouroux, 1813'ün Yağ Asidi Bileşimine Mevsimlerin Etkisi

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Öz: Bu çalışmanın amacı, Sinop sahilinden toplanan *Laurencia obtusa*'nın yağ asidi profilini belirlemektir. Yağ asitleri profili GC/MS ile analiz edilmiş ve mevsimsel değişimleri incelenmiştir. Örnekleme boyunca *L. obtusa'da* 36 farklı yağ asidi tespit edilmiştir. Araştırmada kış mevsiminde %33,78±1,03 ile sonbahar mevsiminde %44,51±1,70 arasında değişen değerlerle en bol bulunan yağ asidinin palmitik asit olduğu belirlendi. Çalışma sonunda *L. obtusa*'nın PUFA ve SFA içerikleri bakımından en zengin olduğu mevsimin ilkbahar, MUFA içeriği bakımından ise sonbahar olduğu belirlenmiştir Ayrıca çalışmada *L. obtusa*'daki PUFA/SFA oranının kıştan yaza doğru %0,10 ile %0,23 arasında değiştiği ve toplam n-6/n-3 PUFA oranının ise yazdan sonbahara doğru %1,14 ile %2,37 değiştiği belirlenmiştir. Aterojenite indeksi (AI) değerinin sonbahardan yaza 1,75 ile 1,97 arasında değiştiği bununla birlikte trombojenisite indeksi (TI) değerinin ise kıştan sonbahara 1,58 ile 2,22 arasında değiştği tespit edilmiştir. Araştırma sonucu mevsimlerin yağ asidi profili üzerinde anlamlı bir etkiye sahip olduğunu göstermiştir.

Anahtar kelimeler: Karadeniz, yağ asiti, GC/MS, makroalg, *Laurencia obtusa*, PUFA.

INTRODUCTION

Macroalgae which are containing abundant essential nutrients especially trace elements and some other bioactive substances play important ecological, biological and environmental roles in coastal environments (Guerry et al., 2009; Carneiro et al., 2014; Olsson et al., 2020). The macroalgae nutritional content is generally rich in

carbohydrates but low in lipids and proteins (Holdt & Kraan, 2011; Neda et al., 2014; Olsson et al., 2020), however contains high amounts of polyunsaturated fatty acids (PUFA), which are highly essential for feeding (Susanto et al., 2016; Paiva et al., 2017). However, the algal contents changes widely in response to various factors, such as temperature, seasonal distribution, pH, life cycle, light, environmental factors, and geographic location (Mansilla & Avila, 2011; Paiva et al., 2017; Barbosa et al., 2020; Seca et al., 2018; Cavaco et al., 2021; Pereira et al., 2021). In addition, studies have revealed that adverse environmental conditions often cause changes in the lipid and unsaturated fatty acid ratios of algae (Guschina & Harwood, 2006; Martins et al., 2016).

There are many studies on the biochemical and nutritional contents of seaweeds in many different regions (Ginneken et al., 2011; Ivanova et al., 2013; Kendel et al., 2015; Panayotova, 2017; Belattmania et al., 2018; Berik & Çankırılıgil, 2019; Berneira et al., 2020; Biris-Dorhoi et al., 2020). Very few studies to date have examined seasonal changes in fatty acids and lipid classes in algae at the same time (Nelson et al., 2005; Schmid et al., 2014), and all seasons have not been compared. Sinop coasts of the Black Sea is rich in algal biomass. However, there is a few study about the fatty acid profiles of macroalgae in literature (Durmaz et al., 2008; Yazıcı et al., 2008; Polat & Ozogul, 2008; Uslu et al., 2013; Turan et al., 2015; Akgül et al., 2015; Pabuçcu et al., 2018; Caf et al., 2015; 2019; Aras & Sayın, 2020) from Turkey. Therefore, the aim of this study is to determine the seasonal changes in the fatty acid profile of *Laurencia obtusa* (Hudson) J.V. Lamouroux, 1813, which is distributed along the coasts of the Sinop Peninsula.

MATERIAL AND METHOD

This study was carried out at four stations (Hamsilos, Akliman, Karakum and DSİ) in Sinop Peninsula coast (Figure 1). The red alga *Laurencia* obtusa (Hudson) J.V. Lamouroux, 1813 samples were collected in 2014 from rocky shores by scuba diving at depth of 0 and 1 meters, seasonally. Macroalgae samples were transferred to the laboratory for identification. For taxonomic categorizations of the species, has been looked at www.algaebase.org (Guiry & Guiry, 2023). In the laboratory, samples were separated from foreign materials (epiphytes, animals, sand), and were washed with distilled water and excess water was absorbed on blotter and then dried in an oven at 60°C for 48 hours (Zhuang & Zhang, 2001; Moustafa & Batran, 2014; Yeşilova et al., 2017). The dried algae samples were dustered by pounding and stored at −20˚C till the analysis. After the sampling period was completed, the analysis of the samples were carried out without waiting too long. For the analysis, 0.5 grams of each sample was used.

Lipid extraction: Lipid extracts were prepared according to Bligh & Dyer (1959), using a mixture of chloroform and methanol. The extracted algal lipid was then transesterified to fatty acid methyl esters (FAME) according to Ichihara et al. (1996). For this process, lipid samples were derivatized into methyl esters in a gas chromatography device (Thermo Scientific Trace 1310). In this process, 0.25 g of extracted oil was taken and dissolved by adding 4 ml of heptane, and then 0.4 ml of 2N KOH was added. This mixture was then vortexed for 2 minutes followed by centrifugation at 5000 rpm for 5 minutes. After centrifugation, 1.5-2 ml of clear heptane phase was taken and transferred to glass tubes and GC/MS analysis was performed. Samples were injected into the device with the help of the autosampler (Autosampler AI 1310).

Figure 1. Sam pling area (Google Maps).

Fatty acid profile: Samples were analyzed by Thermo Scientific ISQ LT model GC/MS gas chromatography mass spectrometry. A 60 m long Trace Gold TG-WaxMS capillary column (Thermo Scientific code: 26088-1540) with an inner diameter of 0.25 µm and a film thickness of 0.25 µm was used for this analysis. The injection block temperature was set to 240°C. The temperature of the column was programmed to remain constant at 100 °C for 3 minutes, then increase to 240 °C in increments of 4 °C/min. A separation ratio of 1:20 was applied using helium gas (1 ml/min) at constant flow as the carrier gas. MS unit (ISQ LT) was used in electron ionization mode (70 eV). Fatty acids were identified by comparing the standard FAME (fatty acid methyl ester) mixture of 37 components according to their arrival time. All analyzes were always done in triplicate.

Lipid quality: To evaluate the lipid quality of the samples and their effects on coronary heart disease risk factors, atherogenicity [AI] and thrombogenicity [TI] indices were calculated according to the method of Ulbricht & Southgate (1991).

Atherogenicity Index (AI) formula is:

$$\mathrm{AI} = \frac{\mathrm{C12:0} + (4 \times \mathrm{C14:0}) + \mathrm{C16:0}}{\sum \mathrm{n-3\ PUFA} + \sum \mathrm{n-6\ PUFA} + \Sigma \mathrm{MUFA}}$$

Thrombogenicity Index (TI) formula is:

$$\mathrm{TI} = \frac{C14:0 + C16:0 + C18:0}{(0.5 \times \Sigma \mathrm{MUFA}) + (0.5 \times \sum \mathrm{n-6\ PUFA}) + (3 \times \sum \mathrm{n-3\ PUFA}) + (\mathrm{n-3/n-6})}$$

Statistical analyses: Analysis of variance (one-way ANOVA) and then Tukey's multiple comparison test were used to determine seasonal differences in the fatty acid profile of the research material, and calculations were made with the SPSS package program (version 24.0). The contribution (percentage) of each fatty acid was taken into account during the calculations. Principal components analysis (PCA) was conducted among the main classes of fatty acids (MUFA, SFA, and MUFA) and sampling periods.

RESULTS

Fatty acid profile of *L. obtusa* expressed as percentage of total fatty acid (FA. dry weight (% of DW) are presented in Table 1. At the end of this study, it was determined 36 different fatty acids (FAs), from C4 to C22 in *L. obtusa* samples. The percentage of the total lipid content of *L. obtusa* showed wide fluctuations, and the total lipid fraction extracted changed between 0.01% DW (C20:3n3c eicosatrienoic acid) to 44.51% DW (palmitic acid). Palmitic acid was the most dominant fatty acid in all seasons, with values ranging from 33.78±1.03% in autumn to 44.51±1.70% in summer. The obtained fatty acids profiles determined to be qualitatively and quantitatively different among the seasons (Table 1, Figure 2). It was determined that the total content of SFA, MUFA and PUFA in *L. obtusa* varied seasonally during the sampling period. The higher contents of ∑SFA and ∑PUFA obtained in spring (61.95% and 14.18%, respectively), but ∑MUFA in autumun (34.84%) (Figure 2).

The major FAs detected in *L. obtusa* were palmitic acid (C16:0), elaidic acid (C18:1 n-9cis), myristic acid (C14:0), stearic acid (C18:0), palmitoleic acid (C16:1), and linoleic acid (C18:2n6c), respectively, which together accounted for mean 80.18% of total fatty acid (TFA) (Table 1). The major fatty acid was palmitic acid (C16:0) from SFAs in the all season. Elaidic acid (C18:1 n-9cis) was the second abundant fatty acid belongst to MUFA. The fatty acid compositions of *L. obtusa* ranged from 59.37±0.57 to 61.94±0.23% saturated (SFAs), from 23.88±0.15 to 34.84±0.38% monounsaturated (MUFAs) and from 5.76±0.20 to 14.18±0.36% polyunsaturated fatty acids (PUFAs) (Table 1, Figure 2).

Statistically significant differences were found among all seasons in the fatty acid profile of *L. obtusa* (ANOVA, Tukey, $P < 0.05$). Significant amounts of palmitic acid and elaidic acid were obtained from *L. obtusa* throughout this study, and statistically significant differences were found between seasons (ANOVA, Tukey, $P<0.05$). It was determined that the summer and winter samples for palmitic acid were significantly different from the autumn and spring samples. However, for elaidic acid, it was determined that the summer and winter samples were significantly different from the spring and autumn samples (Table 1).

Table 1. Seasonal changes in fatty acid profile and nutritional indices of *L. obtusa*

Fatty acid (%)	SEASONS			
	Spring	**Summer**	**Autumn**	**Winter**
C4:0	1.93 ± 0.03^{a}	1.07 ± 0.08^{c}	0.31 ± 0.02^{d}	1.27 ± 0.04^{b}
C6:0	0.12 ± 0.01^{a}	0.10 ± 0.02^{ab}	0.09 ± 0.00^{b}	0.10 ± 0.01^{ab}
C8:0	0.77 ± 0.10^{a}	0.37 ± 0.09^{b}	0.08 ± 0.01^{c}	0.32 ± 0.04^{b}
C10:0	0.10 ± 0.01^{ab}	0.05 ± 0.01^{b}	0.07 ± 0.02^{ab}	0.11 ± 0.03^{a}
C11:0	0.10 ± 0.01^{a}	0.06 ± 0.01^{bc}	0.04 ± 0.01^{c}	0.08 ± 0.01^{ab}
C12:0	0.16 ± 0.01^{a}	0.16 ± 0.02^{a}	0.12 ± 0.01^{b}	0.14 ± 0.02^{ab}
C13:0	0.04 ± 0.01^{a}	0.07 ± 0.01^{a}	0.07 ± 0.02^{a}	0.05 ± 0.01^{a}
C14:0	7.90 ± 0.06^{a}	8.01 ± 0.53^{a}	7.94 ± 0.25^{a}	7.21 ± 0.20^{a}
C15:0	0.55 ± 0.03^{d}	0.62 ± 0.03^{c}	0.96 ± 0.03^{a}	0.73 ± 0.01^{b}
C16:0	40.17 ± 0.39^{b}	44.51 ± 1.70^{a}	38.78 ± 1.03^{b}	43.43 ± 0.45^{a}
C17:0	0.24 ± 0.01^{ab}	0.13 ± 0.04^{b}	0.14 ± 0.11^{ab}	0.31 ± 0.04^{a}
C18:0	6.94 ± 0.04^{a}	3.93 ± 1.41^{b}	8.26 ± 0.16^{a}	4.63 ± 0.05^{b}
C20:0	0.10 ± 0.01^{a}	0.13 ± 0.10^{a}	0.10 ± 0.03^{a}	0.13 ± 0.04^{a}
C21:0	0.12 ± 0.03^{b}	0.47 ± 0.06^{a}	0.11 ± 0.04^{b}	0.19 ± 0.02^{b}
C22:0	0.44 ± 0.05^{ab}	0.43 ± 0.10^{ab}	0.75 ± 0.08^{a}	0.29 ± 0.21^{b}
C23:0	0.12 ± 0.02^{a}	0.10 ± 0.05^{a}	0.17 ±0.13^{a}	0.07 ± 0.02^{a}
C24:0	2.15 ± 0.44^{a}	0.90 ± 0.67^{a}	1.37 ±0.61^{a}	1.14 ± 0.27^{a}
C14:1	0.25 ± 0.01^{d}	0.65 ± 0.01^{a}	0.54 ±0.01^{b}	0.38 ± 0.02^{c}
C15:1	0.08 ± 0.02^{a}	0.11 ± 0.02^{a}	0.14 ±0.02^{a}	0.10 ± 0.05^{a}
C16:1	4.98 ± 0.02^{c}	7.55 ± 0.47^{a}	5.63 ±0.01^{b}	4.92 ± 0.05^{c}
C17:1	0.84 ± 0.03^{b}	1.85 ± 0.32^{a}	0.23 ±0.10^{c}	1.02 ± 0.08^{b}
C18:1 n- 9c	10.22 ± 0.09^{c}	11.26 ± 0.49^{b}	22.34±0.30^{a}	11.81 ± 0.06^{b}
C18:1 n-9t	3.17 ± 0.04^{a}	3.90 ±1.27^{a}	3.42±0.04^{a}	4.36 ± 0.13^{a}
C18:2 n-6t	0.04 ± 0.02^{a}	0.07 ± 0.01^{a}	0.03±0.01^{a}	0.08 ± 0.05^{a}
C20:1	0.36 ± 0.03^{c}	0.29 ± 0.01^{c}	1.08 ± 0.06^{a}	0.52 ± 0.05^{b}
C22:1 n-9	0.64 ± 0.15^{b}	1.26 ± 0.07^{a}	0.50 ± 0.28^{b}	0.52 ± 0.16^{b}
C24:1	2.83 ± 0.11^{a}	1.13 ± 0.06^{c}	0.73 ± 0.11^{d}	1.91 ± 0.19^{b}
C18:2 n-6c(LIN)	7.75 ± 0.06^{a}	3.45 ± 0.29^{c}	2.92 ± 0.03^{d}	6.18 ± 0.04^{b}
C18:3 n-3(ALA)	0.74 ± 0.11^{b}	1.61 ± 0.43^{a}	0.61 ± 0.07^{b}	0.96 ± 0.04^{b}
C18:3 n-6(GLA)	0.47 ± 0.03^{ab}	0.58 ± 0.13^{a}	0.21 ± 0.08^{c}	0.29 ± 0.05^{bc}
C20:2	0.21 ± 0.03^{ab}	0.21 ± 0.02^{ab}	0.19 ± 0.03^{b}	0.29 ± 0.04^{a}
C20:3 n-3	0.03 ± 0.00^{a}	n.d.	0.01 ± 0.00^{b}	0.03 ± 0.00^{a}
C20:3 n-6	n.d.	n.d.	n.d.	n.d.
C20:4 n-6(ARA)	1.40 ± 0.16^{a}	1.44 ± 0.07^{a}	0.78 ± 0.13^{b}	1.66 ± 0.20^{a}
C20:5 n-3(EPA)	2.54 ± 0.09^{b}	2.59 ± 0.36^{b}	0.82 ± 0.01^{c}	4.42 ± 0.07^{a}
C22:2	0.18 ± 0.05^{a}	0.21 ± 0.15^{a}	0.23 ± 0.05^{a}	0.07 ± 0.02^{a}
C22:6 n-3 (DHA)	1.36 ± 0.12^{a}	0.70 ± 0.04^{b}	0.21 ± 0.04^{c}	0.32 ± 0.08^{c}
ΣSFA	**61.94 ± 0.23^{a}**	**61.12 ± 0.30^{ab}**	**59.37 ±0.57^{c}**	**60.19 ± 0.42^{bc}**
ΣMUFA	**23.88 ± 0.15^{d}**	**28.66 ± 0.81^{b}**	**34.84 ± 0.38^{a}**	**25.91 ± 0.31^{c}**
ΣPUFA	**14.18 ± 0.36^{a}**	**10.21± 0.60^{b}**	**5.76 ± 0.20^{c}**	**13.91 ± 0.13^{a}**
AI	**1.88**	**1.97**	**1.75**	**1.82**
TI	**1.76**	**1.73**	**2.22**	**1.58**

Data as represented as a percentage of the total FAME (fatty acid methyl ester) content and presented as mean values of triplicate±SD (n=3), the superscript letters "a–d" in the same line differ significantly at $P < 0.05$ (ANOVA, Tukey HSD).

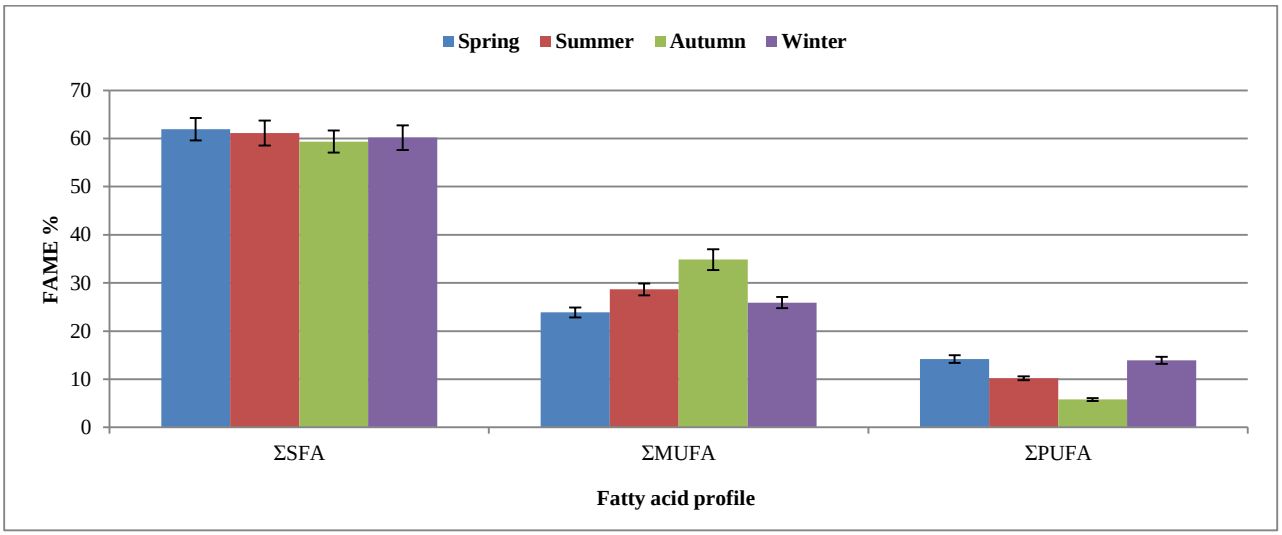

Figure 2. Seasonal ratios of main fatty acid groups (% FAs) in *L. obtusa.*

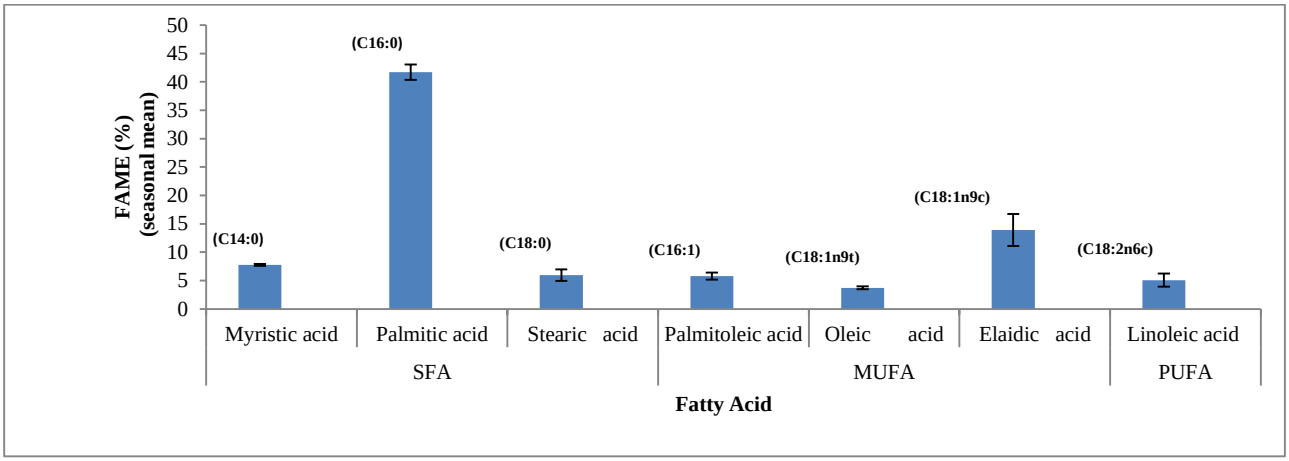

Figure 3. Comparison of the most abundant fatty acids of *L. obtusa* (FAME%, mean of seasons).

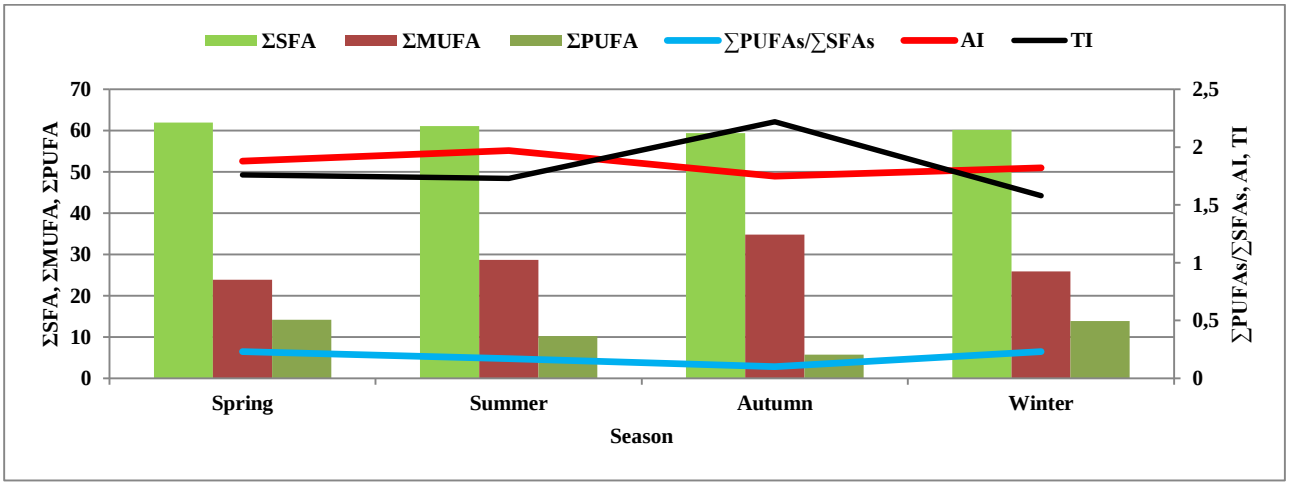

Figure 4. Comparison of saturated fatty acids (SFA), polyunsaturated fatty acids (PUFA), monounsaturated fatty acids (MUFA), ∑PUFA/∑SFA, AI and TI ratios of *L. obtusa* during the sampling period (n = 3).

The predominant fatty acids in this study were found to be saturated fatty acids (SFAs), which contain 4 or 24 carbons (Table 1, Figure 2). Elaidic acid (C18:1. n-9cis) was the most abundant MUFA, representing 22.34±0.30% of total FAME especially in the autumn. On the other hand, linoleic acid (C18:2 n-6c) was the major PUFA (Table 1, Figure 3).

It was determined that the PUFA/SFA ratio in L. obtusa examined in this study varied between 0.10% and 0.23% from winter to summer (Table 2). In addition, the

total n-6/n-3 PUFAs ratio of L. obtusa was found to be greater than 1 and ranged from 1.14 (summer) to 2.37 (autumn) (Table 2). As for the n6/n3 PUFAs ratio, the production of n-3 and n-6 also seemed to present seasonal variations. The amounts of the n-3 PUFA ranged between 1.65±0.10% (autumn) and 5.71±0.12% (winter), while the n-6 PUFAs were verified, between 3.90±0.03% (autumn) and 9.62±0.19% (spring) (Table 2, Figure 3 and 4).

The atherogenicity index (AI) and thrombogenicity index (TI) relating to nutritional factors linked with coronary diseases were calculated from the FA profiles of *L. obtusa* and are summarized in Table 1 and Figure 4. AI was determined to changed 1.75 (in autumun) to 1.97 (in summer), TI was 1.58 (in winter) to 2.22 (in autumun).

Table 2. Seasonal distribution of fatty acid ratios in *L.obtusa* to main groups (given as mean±SD % of total FAME) (n=3).

Group and ratios of fatty acids	Spring	Summer	Autumn	Winter
∑SFAs	61.94±0.23^{a}	61.12±0.30^{ab}	59.37±0.57^{c}	60.18±0.42^{bc}
∑MUFAs	23.88±0.15^{d}	28.66±0.81^{b}	34.84±0.38^{a}	25.91±.0.31^{c}
∑PUFAs	14.18±0.36^{a}	10.22±0.60^{b}	5.79±0.20^{c}	13.91±0.13^{a}
∑PUFAs/∑SFAs	0.23±0.01^{a}	0.17±0.01^{b}	0.10±0.00^{c}	0.23±0.00^{a}
∑n-6 PUFA	9.62±0.19^{a}	5.47±0.36^{b}	3.90±0.03^{c}	8.13±0.24^{d}
∑n-3 PUFA	4.64±0.22^{b}	4.91±0.77^{ab}	1.65±0.10^{c}	5.71±0.12^{a}
n-6/n-3	2.07±0.06^{a}	1.14±0.27^{b}	2.37±0.13^{a}	1.42±0.06^{b}

The superscript letters "a–d" in the same line differ significantly at P < 0.05 (ANOVA, Tukey HSD).

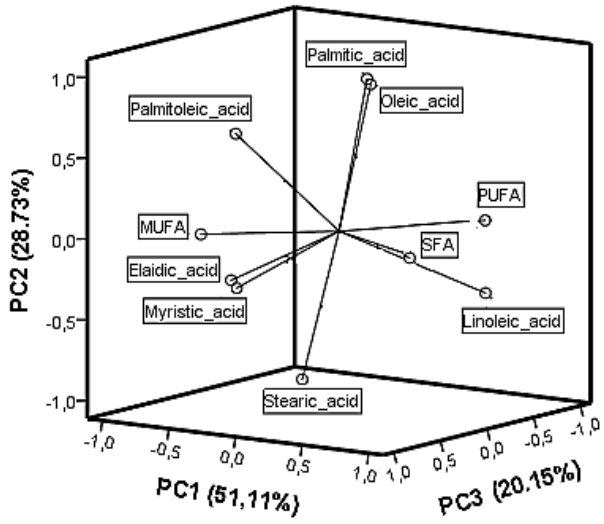

Figure 5. Results of loading plot of multivariate analysis (PCA).

Principal Components Analysis (PCA) was conducted to seasonally evaluate the relationship among the 7 fatty acids (myristic acid, palmitic acid, elaidic acid, palmitoleic acid, stearic acid, oleic acid, linoleic acid) with the highest FA ratio and the total SFA, MUFA, PUFA components. PCA analysis described 99.98% of the total variance, including PC1 (principal component 1, PC2 (principal component 2), and PC3 (principal component 3) (Figure 5). The opposite positions of total PUFA-SFA-linoleik acid and total MUFA-elaidic on the plot explained their inverse correlation with 51.11% of total variation in PC1, while the opposite positions of palmitic acid-oleic acid and steraic acid described in PC2 with 28.73%. The third component (PC3) accounted for 20.15% of total variation with the opposite position of mystric acid/palmitoleic acid

DISCUSSION

Thirty-six components were identified with varying amounts in *L. obtusa* studied in terms of fatty acid composition and were determined that saturated fatty acids (SFA) in abundance (Table 1, Figure 2). This result was consistent with previous studies (Caf et al., 2019; El-Shenody et al., 2019; Farghl et al., 2021), where SFAs were found to be the dominant in *L. obtusa*. It was also determined that the ratio of the fatty acid profile changed significantly ($p<0.05$) along the seasons (Table 1).

In the present study, the highest PUFA and SFA ratio of *L. obtusa* was found in spring, while the highest MUFA ratio was in autumn. Similarly, Nelson et al., (2005) reported that the total macroalgal lipid content increased from winter to spring and decreased in summer. The results of our research showed lower SFA but higher MUFA and PUFA compared to the findings of other studies with *L. obtusa* (El-Shenody et al., 2019; Farghl et al., 2021). However, the results of our study, compared to the findings of another study with *L. obtusa* on the Mediterranean and Black sea coasts, showed higher SFA and MUFA but lower PUFA (Uslu et al., 2013; Caf et al., 2019) (Table 3). Studies have suggested that these variations may be due to various factors such as temperature, age, habitats and environment (Colombo et al., 2006; Zubia et al., 2007; Peng et al., 2015; Farghl et al., 2021). As a matter of fact, the differences among the macroalgae samples obtained from the Sinop coast and the FA profile obtained from similar studies are thought to be due to these reasons.

Table 3. The fatty acids, PUFA/SFA, n-6/n-3 ratios of *Lauencia* spp. in comparison with the current study.

	Red Sea (El-Shenody et al., 2019)	Red Sea (Farghl et al., 2021)	Mediterranean (Caf et al., 2019)	Black Sea (Uslu et al., 2013)	Our study (mean)
SFA	75.6	69.62	48.42	25.24	60.65
MUFA	16.1	18.26	22.55	23.59	28.32
PUFA	8.3	4.68	29.03	42.49	11.02
PUFA/SFA	0.35	0.67	0.6	-	0.18
n-6/ n-3	0.1	0.70	-	-	1.75

Studies have demontrated that nutritional indices such as AI and TI ratios greater than one in foods have negative effects on health, the nutritional quality decreases with the increase in these ratios, and the n6/n3 PUFA ratios in algae are reflected in the mentioned health indices (Ulbricht & Southgate, 1991; Kumar et al., 2011; Kumari et al., 2010, 2013; Chen et al., 2016; Bouafif et al., 2018; Schmid et al., 2018; Moreira et al., 2021). In terms of human health, the recommended maximum dietary ratio of n-6/n-3 PUFAs is 4.0 (HMSO, 1994) and the minimum dietary ratio of PUFA/SFAs is 0.45 (Wood et al., 2004; Kumar et al. 2011). In this study, it was determined that n-6/n-3 PUFA ratio and PUFA/SFA ratio were below the recommended diet ratios. On the other hand, AI and TI ratios were found to be higher than the stated ratio (>1.0) in this study. The reason for this situation is probably due to the high palmitic acid and myristic acid ratio we detected in *L obtusa*. (Table 2; Figure 4).

CONCLUSION

In conclusion, our findings showed that *L. obtusa* has the highest SFA content compared to unsaturated fatty acids and also lower omega-3 ratio compared to omega-6, thus promoting higher AI and TI. As a result of the study, it was revealed that *L. obtusa* is not suitable for human nutrition because of the lower n-6/n-3 PUFA and the PUFA/SFA ratio and the higher AI and TI ratios than normal limits. However, *L. obtusa* can be an important source of fatty acids with highly obtained palmitic acid, myristic acid and stearic acid from SFA, palmitoleic acid, oleic acid and elaidic acid from MUFA and linoleic acid (LA) from PUFA. The rates of docosahexaenoic acid (DHA) varying between 0.21% and 1.36% and eicosapentaenoic acid (EPA) varying between 0.82% and 4.42% obtained in our study, it has been showed that *L. obtusa* can be an important source of n-3 fatty acids. The result of this study show that *L. obtusa* can be used in different fields, due to the fatty acids it contains. In addition, our results demonstrated that the seasons have a significant effect on the fatty acid profile of the studied seaweed. Therefore, it is thought that more comprehensive studies should be done in terms of evaluating the usability of macrolag species distributed in Turkey in different areas.

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