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RESEARCH ARTICLE

Biochemical composition of some red and green seaweeds from Iskenderun Bay, the northeastern Mediterranean coast of Turkey

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Abstract

The present study was aimed to determine total protein, total carbohydrate, total phenolic substances and pigment contents of some red and green seaweed or macroalgae collected from Iskenderun Bay, the northeastern Mediterranean coast of Turkey between April-June 2013. Totally five seaweed samples, three red (*Jania rubens*, *Laurencia papillosa*, *Laurencia obtusa*) and two green (*Ulva lactuca*, *Codium fragile*), were analyzed. The highest protein content was obtained from *L. obtusa* (142.94±3.24 mg g^{-1}) whereas the lowest protein content was obtained from *J. rubens* (13.82±0.58 mg g^{-1}). The carbohydrate yields of macroalgae varied from 155.23±1.79 to 643.93±4.68 mg g^{-1}, the maximum carbohydrate concentration was recorded from green alga, *C. fragile,* (643.93±4.68 mg g^{-1}) followed by green alga, *U. lactuca,* (506.69±9.19 mg g^{-1}). The total phenolic contents of seaweed varied from 0.053±0.01 to 0.529±0.11 mg g^{-1} and the maximum phenolic substance content was recorded from *L. obtusa* (0.529±0.11 mg g^{-1}). The green alga, *U. lactuca*, showed the highest Chlorophyll-*a* and carotene content (2.905±0.12 and 0.941±0.04 mg g^{-1} respectively) among these seaweeds.

Keywords: Biochemical composition, red seaweed, green seaweed, Iskenderun Bay

Introduction

Seaweeds have been used as food, animal feeds, fertilizer and as sources of traditional medicine in many Asian civilizations since ancient times. Seaweeds are excellent dietary sources of vitamins and trace minerals (Kumar *et al.* 2008), but they also contain bioactive substances like polysaccharides, proteins, lipids and polyphenols, with antibacterial, antiviral and antifungal properties (Kumar *et al.* 2008). This gives seaweed great potential as a supplement in functional food or for the extraction of compounds. Physiologically active substances in marine algae are classified into two types based on the difference in the mechanisms: (1) non-absorbed high-molecular materials like dietary fibres and (2) low-molecular materials, which are absorbed and affect the maintenance of human homeostasis directly (Murata and Zhang 2007; Holdt and Kraan 2011). Therefore, biochemical diversity of seaweeds derived from active components become a rich source of novel chemical entities for the use as functional ingredients in many industrial applications such as functional foods ("functional food" term is reserved for foods and food components that have been demonstrated to provide specific health benefits beyond basic nutrition), pharmaceuticals and cosmeceuticals (Wijesinghe and Jeon 2012). According to Zemke-White and Ohno (1999), about 221 seaweed species (32 Chlorophyta, 64 Phaeophyta and 125 Rhodophyta) are used for a variety of purposes throughout the world. Of these species, about 66% are used for food in Far East. Over the past few decades, the consumption of seaweed products has increased in Western countries. In these days, approximately 15–20 edible algae strains are being marketed for consumption in Europe. They are excellent dietary sources of vitamins, proteins, carbohydrates, trace minerals and vitamins (Burtin 2003; Polat and Ozogul 2013).

Seaweeds are also known to contain bioactive products that display antibacterial, antiviral and antifungal properties (Trono 1999). Generally seaweeds at the surf zone also provide a niche environment for juvenile fishes and wrack-inhabiting organisms (Lenanton *et al.* 1982). Several studies on the biochemical and nutritional composition of various seaweeds, collected from different parts of the world, have been conducted to fully exploit the nutritional value of seaweeds (Renaud and Luong-Van 2006; Banerjee *et al.* 2009; Gressler *et al.* 2011; Ahmad *et al.* 2012; Rohani-Ghadikolaei *et al.* 2012; Khairy and El-Shafay 2013). The biochemical composition of marine seaweeds is generally known to be highly influenced by geographical location and local environmental conditions (Renaud and Luong-Van 2006; Mohamed *et al.* 2012).

Turkey is a potential algae production country with its long coastlines that are rich in biodiversity and biomass. Studies on algae in Iskenderun Bay are generally conducted on the taxonomy, heavy metal accumulation in macroalgae (Taskın *et al.* 2001; Olgunoğlu and Polat 2007; Ozvarol 2009). On the other hand, there are few studies on the biochemical and nutritional composition of macroalgae from the northeastern Mediterranean coast of Turkey (Polat and Ozogul 2008; 2009; 2013).

Therefore, the aim of this study was to determine total protein, total carbohydrate, total phenolic and pigment contents of some red and green seaweeds collected from Iskenderun Bay, the northeastern Mediterranean coast of Turkey.

Materials and Methods

Sample collection and preparation

In total, five seaweeds, three red (*Jania rubens* (Linnaeus) Lamouroux, *Laurencia papillosa* (C. Agardh) Greville, *Laurencia obtusa* (Hudson) J.V. Lamouroux) and two green (*Ulva lactuca* (Linnaeus), *Codium fragile* (Suringar)) were collected from 0-0.5 m depth in Iskenderun Bay (36°33′ N - 35°34′ E, 36°18′ N - 35°46′ E, 36°54′ N - 36°00′ E, 36°35′ N - 36°11′ E), the northeastern Mediterranean coast of Turkey between April-June 2013 (Figure 1).

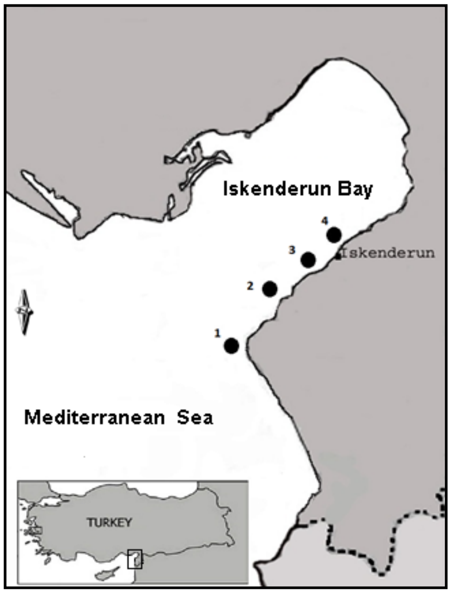

Figure 1. Sampling sites

After collection from four different experimental stations twice a month for three months (Figure 1), the seaweed samples were cleaned and washed with seawater to remove epiphytes and other extraneous matter and immediately transported to the laboratory in an ice cooler box to maintain the low temperature and moisture during the transport. In the laboratory, the samples were thoroughly cleaned by rinsing with distilled water and dried with tissue paper to remove excess water. The moisture and ash of the fresh samples was immediately analyzed. The remaining cleaned seaweed samples were then oven dried at 40°C. After reaching constant weight, the dried samples were ground (for 5 min) into a fine powder using a Warring blender before being packed and stored in a freezer at -20°C until further chemical analysis. All chemical analyses of seaweed samples were carried out in triplicate.

Biochemical composition

The dry matter and ash contents of seaweeds were determined according to Tomoselli (1997) and AOAC (2000), respectively. The dry matter was determined by oven drying of seaweed at 103°C until a constant weight was obtained. The ash content was determined by placing samples in a muffle furnace at 525°C for 12 h and then weighing the residue. Brown seaweed total protein was determined by the Lowry method (Lowry 1951) in accordance with Ozyılmaz (2005) with some modifications. The total carbohydrate was estimated following the Phenol-Sulphuric acid method of Dubois *et al.* (1956) as mg g^{-1} dw (Dry weight). Total phenolic was determined by the Folin-Ciocalteu method in accordance with Yıldırım (2010) with some modifications. Pigment extraction was performed in methanol, at 4°C, for 20 h. Chlorophyll *a* and total carotenoid were determinated spectrophotometrically as described by Durmaz *et al.* (2008) as: Carotene (mg g^{-1})= 4.5^{*} A475 (Zou and Richmond 2000); Chlorophyll-*a* (mg g^{-1}) = 13.9 *A666 (Sanchez *et al.* 2005).

Statistical Analysis

Data were analyzed using SPSS (Statistical Package for the Social Sciences) version 16.0. One-way ANOVA test was used to compare the differences between the mean value of dry matter, ash, total protein, total carbohydrate, and total phenolic and pigments contents of each seaweed. Duncan multiple range test was applied to determine the differences between species. A significant difference was considered at the level of p<0.001.

Results

The biochemical compositions of red and green seaweeds collected from Iskenderun Bay are given in Table 1.

Table 1. The biochemical compositions of some red and green seaweeds collected from Iskenderun Bay, the Northeastern Mediterranean coast of Turkey (dry weight)

Seaweeds	Component				
	Dry matter (%)	**Protein (mg g^{-1})**	**Carbohydrate (mg g^{-1})**	**Total Phenolic Content (mg g^{-1})**	**Ash (%)**
Red Seaweeds					
Laurensia obtusa	29.28 ± 0.27^{c}	142.94 ± 3.24^{d}	199.69 ± 9.19^{a}	0.529 ± 0.11^{d}	20.25 ± 0.36^{b}
Laurensia papillosa	27.35 ± 0.51^{b}	23.63 ± 0.59^{b}	155.23 ± 1.79^{a}	0.246 ± 0.01^{c}	23.33 ± 0.45^{c}
Jania rubens	32.68 ± 0.69^{e}	13.82 ± 0.58^{a}	374.02 ± 7.29^{b}	0.053 ± 0.01^{a}	26.50 ± 0.37^{d}
Green Seaweeds					
Codium fragile	15.47 ± 0.45^{a}	25.49 ± 1.02^{b}	643.93 ± 4.68^{d}	0.095 ± 0.01^{ab}	21.79 ± 0.52^{bc}
Ulva lactuca	30.89 ± 0.30^{d}	56.76 ± 2.81^{c}	506.69 ± 9.19^{c}	0.221 ± 0.01^{bc}	12.37 ± 0.72^{a}

Note: Values (mean ± S.D. of triplicate) with different letters in each column indicate significant differences (p<0.001)

The dry matters of macroalgae ranged from 15.47±0.45% to 32.68±0.69%, and there were significant statistical difference these macroalgae (p<0.001). The highest dry matter was obtained from *J. rubens* (32.68±0.69%) among red and green macroalgae (Table 1). In the same way, the ash contents of macroalgae varied from 12.37±0.72 to 26.50±0.37 %, and there were significant statistical difference between red and green macroalgae ($p<0.001$). The highest percent of ash was measured in *J. rubens* (26.50±0.37 %) followed by *L. papillosa* (23.33±0.45%) and *C. fragile* (21.79±0.52%).

Protein contents of macroalgae varied from 13.82±0.58 to 142.94±3.24 mg g^{-1} and there was significant statistical difference between red and green macroalgae ($p<0.001$). The maximum protein was recorded in *L. obtusa* (142.94±3.24 mg g^{-1}) followed by *U. lactuca* (56.76±2.81 mg g^{-1}), *C. fragile* (25.49±1.02 mg g^{-1}) and *L. papillosa* (23.63±0.59 mg g^{-1}). The minimum protein concentration was observed in *J. rubens* (13.82±0.58 mg g^{-1}) (Table 1).

The carbohydrate concentrations of macroalgae varied from 155.23±1.79 to 643.93±4.68 mg g^{-1} and there were significant statistical difference between red and green macroalgae ($p<0.001$). The maximum carbohydrate concentration was recorded in *C. fragile* (643.93±4.68 mg g^{-1}) followed by *U. lactuca* (506.69±9.19 mg g^{-1}), *J. rubens* (374.02 ± 7.29 mg g^{-1}) and *L. obtusa* (199.69 ± 9.19 mg g^{-1}). The minimum carbohydrate content was observed in *L. papillosa* (155.23±1.79 mg g^{-1}) (Table 1).

The total phenolic subtances' contents of macroalgae varied from 0.053±0.01 to 0.529±0.11 mg g^{-1} and there were significant statistical difference between red and green macroalgae ($p<0.001$). The maximum phenolic content was recorded in *L. obtusa* (0.529±0.11 mg g^{-1}). The minimum phenolic contents were observed in *J. rubens* (0.053±0.01 mg g^{-1}) (Table 1).

The pigment contents of the red and green seaweeds collected from Iskenderun Bay were summarized in Table 2. *U. lactuca* showed the highest Chlorophyll-*a* and carotene content (2.905±0.12 and 0.941±0.04 mg g^{-1}, respectively) among these macroalgae. The lowest Chlorophyll-*a* and Carotene contents were observed in *L. papillosa* and *J. rubens* (Table 2).

Table 2. Pigment contents of some red and green seaweeds collected from Iskenderun Bay, the northeastern Mediterranean coast of Turkey (dry weight)

Seaweeds	**Pigments**	
	Chlorophyll-*a* (mg/g)	**Carotene (mg/g)**
Red seaweeds		
Laurensia obtusa	0.357 ± 0.03^{b}	0.116 ± 0.01^{b}
Laurensia papillosa	0.051 ± 0.00^{a}	0.017 ± 0.00^{a}
Jania rubens	0.125 ± 0.04^{a}	0.029 ± 0.00^{a}
Green seaweeds		
Codium fragile	0.204 ± 0.03^{ab}	0.066 ± 0.01^{ab}
Ulva lactuca	2.905 ± 0.12^{c}	0.941 ± 0.04^{c}

Note:Values (mean ± S.D. of triplicate) with different letters in each column indicate significant differences ($p<0.001$)

Discussion

The present study, investigation of the biochemical compositions of the three red (*Jania rubens*, *Laurencia papillosa*, *Laurencia obtusa*) and two green (*Ulva lactuca*, *Codium fragile*) seaweeds collected from Iskenderun Bay in spring 2013 revealed that the nutritional contents of these species show remarkable variations in Iskenderun Bay. This is a preliminary report to our knowledge regarding total protein, total carbohydrate, total phenolic and pigment contents of these macroalgae collected from Iskenderun Bay, the northeastern Mediterranean coast of Turkey.

In this study, the highest ash content was observed in the red seaweed *J. rubens* (26.50%), while the lowest was observed in *U. lactuca* (12.37%). The range of ash content determined in the present study was similar to that reported by Rohani-Ghadikolaei *et al.* (2012) and Matanjun *et al.* (2009) but slightly lower than those reported by Renaud and Luong-Van (2006). Proteins were the major component in the proximate composition of all the macroalgae examined in the present study. The protein content ranged from 13.82±0.58 mg g^{-1} in *J. rubens* to 142.94±3.24 mg g^{-1} in *L. obtusa*. In comparison with the other algal species, the highest content of protein was determined in *L. obtusa* in the Iskenderun Bay. Similarly, Burtin (2003) reported that the protein concentration of red and green macroalgae was at 10-30% of dry weight. However Rohani-Ghadikolaei *et al*. (2012) found higher level of protein concentrations in *U. lactuca (*17.1% dry weight*)* and red seaweeds (16.5-19.3% dry weight) than the protein contents of *U. lactuca* and red seaweeds found in the present study. These levels probably varied depending on season and environmental differences (e.g. salinity, temperature, dissolved oxygen). The protein content of seaweeds varies not only between species but also between habitats, levels of maturity and time of the year (Zucchi and Necchi 2001; Stirk *et al.* 2007).

Carbohydrates were the major component in the proximate composition of all the seaweeds examined in the present study. The carbohydrate content ranged from 155.23±1.79 in *L. papillosa* to 643.93±4.68 mg g^{-1} in *C. fragile*. The carbohydrate content in *U. lactuca* were also significantly higher compared to the red seaweeds. These results are comparatively lower than those reported by Ortiz *et al.* (2006) for *U. lactuca* (61.5%), but similar to those obtained by Chakraborty and Santra (2008) for *U. lactuca* (35.3%), and by Manivannan *et al.* (2008) for red seaweeds. Also, similar range of carbohydrate content was previously reported by Burtin (2003) and Matanjun *et al.* (2009) for various seaweeds.

Phenolic compounds are commonly found in plants and have been reported to have several biological activities including the antioxidant activity. The major part of antioxidant molecules are polyphenolic compounds (Cao *et al.* 1997). Therefore, a number of studies have focused on the biological activities of phenolic compounds. In this study, the red alga *L. obtusa* was found to contain total phenolic compound of 0.529 mg g^{-1}. Phenolic compounds are widely distributed in seaweeds and are known to exhibit higher antioxidative activities and chemo preventive agents (Bravo 1998). According to this result, it is clearly indicated that *L. obtusa* have a high antioxidant activity.

In this study, pigment contents of some red and green macroalgae collected in Iskenderun Bay were determined and *U. lactuca* showed the highest Chlorophyll-*a* and Carotene content (2.905±0.12 and 0.941±0.04 mg g^{-1} respectively) among these macroalgae. Several studies have reached the same conclusion that the biochemical contents of macroalgae depend not only on season and geography (Haroon *et al.* 2000; Stirk *et al.* 2007), but also on the nutrient content of the environment (Mohamed *et al.* 2012). Moreover, Zucchi and Necchi (2001) reported that physical factors such as light density and quality, photoperiod and temperature can also alter pigment contents.

Seaweeds exhibit a particular odor and taste; therefore new species should be investigated with respect to their nutritional values for use as vegetables or as food ingredients to address changes in human food habits and lifestyles. Additionally, these seaweeds could be potentially rich sources of natural antioxidants, and the findings on total phenolic contents and other components can be used as a basis for more advanced research on seaweed antioxidant capability which will enrich the national food composition database.

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İskenderun Körfezi (Kuzeydoğu Akdeniz) kıyısında dağılım gösteren bazı kırmızı ve yeşil makroalg türlerinin biokimyasal içerikleri

Özet

Bu çalışmada, İskenderun Körfezi (Kuzeydoğu Akdeniz) kıyısalından toplanan kırmızı ve yeşil makroalg türlerinin toplam protein, toplam karbonhidrat, toplam fenolik bileşik ve pigment içerikleri belirlendi. Toplamda üç kırmızı (*Jania rubens*, *Laurencia papillosa*, *Laurencia obtusa*) ve iki yeşil (*Ulva lactuca, Codium fragile*) olmak üzere beş makroalg türünün analizleri yapıldı. En yüksek protein içeriği *L. obtusa* (142,94±3,24 mg g^{-1})'da elde edilirken, en düşük protein içeriği *J. rubens* (13,82±0,58 mg g^{-1}) bulunmuştur. Makroalglerin karbonhidrat konsantrasyonları 155,23±1,79 ile 643,93±4,68 mg g^{-1}arasında değişmiştir. En yüksek karbonhidrat konsantrasyonu *C. fragile,* (643,93±4,68 mg g^{-1}) türünde kaydedilirken bunu (506,69±9,19 mg g^{-1})ile *U. lactuca* takip etmiştir. Makroalglerin toplam fenolik içerikleri 0,053±0,01 ile 0,529±0,11 mg g^{-1} arasında olup, en yüksek fenolik içeriği 0,529±0,11 mg g^{-1} ile *L. obtusa* türünde

belirlenmiştir. Aynı zamanda çalışılan makrolagler arasında en yüksek klorofil-a ve karoten içeriği 2,905±0,12 ve 0,941±0,04 mg g^{-1} ile *U. lactuca* türünde tespit edilmiştir.

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