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RESEARCH ARTICLE

Biochemical composition of some brown algae from Iskenderun Bay, the northeastern Mediterranean coast of Turkey

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Abstract

The present study aimed to determine total protein, total carbohydrate, total phenolic substances and pigment contents of brown algae collected in Iskenderun Bay, the northeastern Mediterranean coast of Turkey. Totally eight brown algae samples (*Cystoseira barbata, Cystoseira corniculata, Cystoseira compressa, Dictyota dichotoma, Padina pavonia, Sargassum vulgare, Stypocaulon scoparium, Stypopodium schimperii*) were analyzed. The highest protein content was obtained from *S. schimperii* (65.19±4.32 mg g^{-1}) whereas the lowest protein content was obtained from *C. compressa* (28.97±3.73 mg g^{-1}). The carbohydrate yields of macroalgae varied from 12.25±1.60 to 47.92±5.66 mg g^{-1}, the maximum carbohydrate concentration was recorded from *D. dichotoma* (47.92±5.66 mg g^{-1}) followed by *S. schimperii* (41.92±2.32 mg g^{-1}). The total phenolic contents of algae varied from 0.364±0.04 to 1.312±0.03 mg g^{-1} and the maximum phenolic substance content was recorded in *S. schimperi* (1.312±0.03 mg g^{-1}). *S. schimperii* showed the highest Chlorophyll-*a* and Carotene content (4.09±0.60 and 0.536±0.05 mg g^{-1}, respectively) among the brown algae. According to the results obtained from this study, these macroalgae species, especially *S. schimperii*, can be regarded as a potential source for food, pharmacology and cosmetic industry.

Keywords: biochemical composition, brown algae, Iskenderun Bay

Introduction

Algae are a commercially important and renewable marine resource that are being studied on the use of many industrial applications such as in food, cosmetics, chemistry, dye, and medicine, nowadays. Biologically active compounds of algae (phlorotannins, carotenoids, alginic acid, fucoidan, peptides) are being demonstrated to play a significant role in prevention of certain degenerative diseases, such as cancer, inflammation, arthritis, diabetes and hypertension (Burtin 2003). Therefore, immense biochemical diversity of algae 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, pharmaceuticals and cosmeceuticals (Wijesinghe and Jeon 2012). According to (Zemke-White and Ohno 1999), about 221 alga species (32 *Chlorophyta*, 64 *Phaeophyta* and 125 *Rhodophyta*) are being 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 algal 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).

The quantity of macroalgal pigment is mostly used to determine algal biomass. Many studies indicate that extreme environmental factors, e.g. salinity, temperature, and nutrients, cause a high rate of pigment production (Dere *et al.* 2003; Zucchi and Necchi 2001).

Several studies on the biochemical and nutritional composition of various algae, collected from different parts of the world, have been conducted to fully exploit the nutritional value of algae (Renaud and Luong-Van, 2006; Gressler *et al.* 2011; Ahmad *et al.* 2012; Khairy and El-Shafay 2013). The biochemical composition of marine algae 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 in Iskenderun Bay are generally conducted on the taxonomy, heavy metal accumulation of macroalgae (Taskın *et al.* 2001; Olgunoğlu and Polat 2007; Ozvarol 2009). On the other hand, there are a few studies on the biochemical and nutritional composition of macroalgae from the northeastern Mediterranean coast of Turkey (Polat and Ozogul 2008; 2009; 2013). However, studies on brown algae from Iskenderun Bay are very limited.

Therefore, the aim of this study was to determine total protein, total carbohydrate, total phenolic and pigment contents of the eight brown macroalgae collected from Iskenderun Bay, the northeastern Mediterranean coast of Turkey.

Materials and Methods

Sample collection and preparation

Macroalgae samples 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 in April-June 2013 (Figure 1).

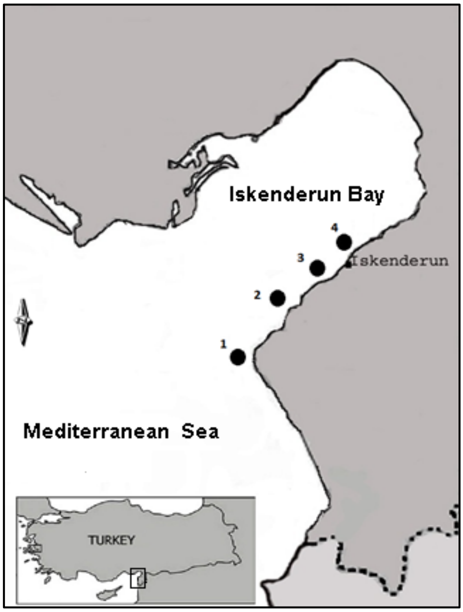

Figure 1. Sampling sites

Eight marine algal species belong to *Phaeophyta* or *Ochrophyta* (brown algae) were collected that are: *Cystoseira barbata* (Goodenough &nd Wood.) C.Agardh, *Cystoseira corniculata* (Turner) Zanardini, *Cystoseira compressa* (Esper) Gerloff & Nizamuddin, *Dictyota dichotoma* (Hudson) Lamouroux, *Padina pavonia* (Linnaeus) Gaillon, *Sargassum vulgare* C. Agardh, *Stypocaulon scoparium* (L.) Kützing [*Halopteris scoparia* (L.) Sauvageau], *Stypopodium schimperi* (Buchinger ex Kützing) Verlague & Boudour.

After collection from four stations (Figure 1), the algae 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 sorted and then 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 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 algae samples were carried out in triplicate.

Biochemical composition

The dry matter and ash contents of algaewere determined according to Vonshak (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 algae total protein was determined by the Lowry method (Lowry 1951) in accordance with a protocol described by 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 a protocol described by 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) 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 collected in this study was analyzed using SPSS (Statistical Package for the Social Sciences) version 16.0. One way ANOVA was used to compare the differences between the mean value of dry matter, ash, total protein, total carbohydrate, total phenolic and pigments contents of algal species. Also, Duncan multiple range test was used to determine the differences between species. A significant difference was considered at the level of $p<0.05$.

Results

The biochemical compositions of the eight brown algae collected from Iskenderun Bay are given in Table 1.

Table 1. The biochemical compositions of the eight brown seaweeds collected from Iskenderun Bay, the Northeastern Mediterranean coast of Turkey (dry weight)

Brown algae	Components				
	Dry matter (%)	**Protein (mg g^{-1})**	**Carbohydrate (mg g^{-1})**	**Total Phenolic Content (mg g^{-1})**	**Ash (%)**
C. compressa	30.30 ± 0.99[c]	28.97 ±3.73[a]	12.25 ± 1.60[a]	0.644 ± 0.10[d]	1.66 ± 0.29[a]
D. dichotoma	13.07 ±1.32[a]	40.44 ± 3.27[bc]	47.92 ± 5.66[e]	0.851 ± 0.06[e]	7.60 ± 1.614[bc]
P. pavonia	32.25 ±1.05[c]	31.91 ± 4.59[a]	14.74 ± 3.08[a]	0.405 ± 0.02[ab]	18.19 ± 2.66[e]
S. vulgare	25.13 ±1.05[b]	35.09 ± 2.49[ab]	31.03 ± 6.59[c]	0.512 ± 0.05[c]	16.07 ± 2.92[de]
S. schimperi	30.13 ±0.87[c]	65.19 ± 4.32[e]	41.92 ± 2.32[d]	1.312 ± 0.03[f]	4.66 ± 1.72[ab]
C. corniculata	31.61 ±0.88[c]	43.72 ± 3.22[c]	20.74 ± 1.37[b]	0.469 ± 0.02[bc]	8.67 ± 2.02[c]
C. barbata	37.73 ±0.92[d]	53.18 ± 9.00[d]	19.71 ± 3.40[b]	0.456 ± 0.06[bc]	14.13 ± 1.19[d]
S. scoparium	13.93 ±2.85[a]	35.88 ± 2.88[ab]	13.43 ± 1.07[a]	0.364 ± 0.04[a]	7.43 ± 2.43[bc]

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

The dry matters of macroalgae ranged from 13.07±1.32 % to 37.73±0.92 %, and there were significant statistical differences between brown algae ($p<0.001$). The highest dry matter was obtained from *C. barbata* (37.73±0.92%) among eight brown algae (Table 1). In the same way, the ash contents of algae varied from 1.66±0.29 to 18.19±2.66 %, and there were significant statistical differences between brown algae ($p<0.001$). The highest percent of ash was measured in *P. pavonia* (18.19±2.66 %) followed by *S. vulgare* (16.07±2.92 %) and *C. barbata*. (14.13±1.19 %).

The protein contents of macroalgae varied from 28.97±3.73 to 65.19±4.32 mg g^{-1} and there were significant statistical differences between brown algae ($p<0.001$). The maximum protein was recorded in *S. schimperi* (65.19±4.32 mg g^{-1}) followed by *C. barbata* (53.18±9.00 mg g^{-1}), *C. corniculata* (43.72±3.22 mg g^{-1}) and *S. scoparium* (35.88 ± 2.88 mg g^{-1}). The minimum protein concentration was observed in *C. compressa* (28.97±3.73 mg g^{-1}) followed by *P. pavonia* (31.91±4.59 mg g^{-1}), *S. vulgare* (35.09 ± 2.49 mg g^{-1}) and *D. dichotoma* (40.44 ± 3.27 mg g^{-1}) (Table 1).

The carbohydrate concentrations of macroalgae varied from 12.25±1.60 to 47.92±5.66 mg g^{-1} and there were significant statistical differences between brown macroalgae ($p<0.001$). The maximum carbohydrate concentration was recorded in *D. dichotoma* (47.92±5.66 mg g^{-1}), followed by *S. schimperi* (41.92±2.32 mg g^{-1}) and *S. vulgare* (31.03 ± 6.59 mg g^{-1}). The minimum carbohydrate content was observed in *C. compressa* (12.25±1.60 mg g^{-1}), followed by *S. scoparium* (13.43±1.07 mg g^{-1}), *P. pavonia* (14.74±3.08 mgg^{-1}), *C. barbata* (19.71±3.40 mg g^{-1}) and *C. corniculata* (20.74±1.37 mg g^{-1}) (Table 1).

The total phenolic subtances of macroalgae varied from 0.364±0.04 to 1.312±0.03 mg g^{-1} and there were significant statistical differences between brown macroalgae ($p<0.001$). The maximum phenolic content was recorded in *S. schimperi* (1.312±0.03 mg g^{-1}). The minimum phenolic contents were observed in *S. scoparium* (0.364±0.04 mg g^{-1}), followed by *P. pavonia* (0.405±0.02 mg g^{-1}), *C. barbata* (0.456±0.06 mg g^{-1}), *C. corniculata* (0.469±0.02 mg g^{-1}), *S. vulgare* (0.512±0.05 mg g^{-1}), *C. compressa* (0.644±0.10 mg g^{-1}) and *D. dichotoma* (0.851±0.06 mg g^{-1}) (Table 1).

Table 2. Pigment contents of the eight brown algae collected from Iskenderun Bay, the northeastern Mediterranean coast of Turkey

	Pigments	
Brown algae	**Chlorophyll-*a* (mg g^{-1})**	**Carotene (mg g^{-1})**
C. compressa	1.297 ± 0.35^a	0.234 ± 0.07^a
D. dichotoma	1.427 ± 0.62^a	0.207 ± 0.02^a
P. pavonia	2.187 ± 0.42^b	0.610 ± 0.16^b
S. vulgare	0.894 ± 0.19^a	0.111 ± 0.03^a
S. schimperi	4.09 ± 0.60^c	0.536 ± 0.05^b
C. corniculata	0.839 ± 0.07^a	0.154 ± 0.04^a
C. barbata	1.056 ± 0.20^a	0.180 ± 0.06^a
S. scoparium	1.066 ± 0.55^a	0.132 ± 0.04^a

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

The pigment contents of the eight brown algae collected from Iskenderun Bay were summarized in Table 2. *S. schimperi* showed the highest Chlorophyll-*a* and Carotene content (4.09±0.60 and 0.536±0.05 mg g^{-1}, respectively) among the brown algae. The lowest Chlorophyll-*a* and Carotene content is observed in *C. corniculata* and *S. vulgare* (Table 2).

Discussion

The present study on the biochemical compositions of the eight brown macroalgae (*C. compressa, D. dichotoma, P. pavonia, S. vulgare, S. schimperi, C. corniculata*, *C. barbata* and *S. scoparium*) collected in Iskenderun Bay in spring 2013 revealed that the nutritional contents of these species show remarkable variation in Iskenderun Bay. This is a preliminary report to our knowledge regarding total protein, total carbohydrate, total phenolic and pigment contents of the eight brown macroalgae collected from Iskenderun Bay, the northeastern Mediterranean coast of Turkey.

Proteins were the major component in the proximate composition of all the macroalgae examined in the present study. The protein content ranged from 65.19±4.32 mg g^{-1} in *S. schimperi* to 28.97±3.73 mg g^{-1} in *C. compressa*. In comparison with the other algal species, the highest content of protein was determined in *S. schimperi* in Iskenderun Bay. Similarly, Burtin (2003) reported that the protein concentration of brown macroalgae was at 5-11% of dry weight. However, Polat and Ozogul (2013) found lower level of protein concentration in *S. schimperi* (2.68±0.06% dry weight) than the protein content of *S. schimperi* found in the present study. These levels probably varied depending on season and environmental differences. The protein content of algae varies not only between species but also between habitats, maturity and time of the year (Zucchi and Necchi 2001; Stirk *et al.* 2007).

The carbohydrate content in *S. schimperi* was significantly higher than those of other brown macroalgae. The present results are comparatively similar to those reported by Demirel *et al.* (2012) who studied brown macroalgae from the Aegean Sea (Turkey). Similar range of carbohydrate content was also previously reported by Burtin (2003) and Matanjun *et al.* (2009) for various algae.

Phenolic compounds play a significant role in the cell defense against biotic and abiotic stresses in macroalgae. In this study, the maximum phenolic content was recorded from *S. schimperi* (1.312±0.03 mg g^{-1}) among other brown macroalgae. Similarly, Chkhikvishvili and Ramazanov (2000) showed that the highest content of phenolic substances was determined in brown macroalgae in the Canary Islands (Spain). In addition, Demirel *et al.* (2012) reported that *P. pavonia* showed the highest total phenol content (21.81±0.50 mg GAE/10 g) than four other brown macrolagae (*C. sinuosa, P. fascia, S. lomentaria, D. spiralis*) in the Aegean Sea (Turkey).

In this study, pigment contents of the eight brown macroalgae collected from Iskenderun Bay were determined and *S. schimperi* showed the highest Chlorophyll-*a* and Carotene content (4.09±0.60 and 0.536±0.05 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.

These algae could be potentially rich sources of natural antioxidants, and the findings on total phenolic contents and other components can be used asa basis for more advanced research on algal antioxidant capability which will enrich the national food composition database.

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İskenderun Körfezi (Kuzeydoğu Akdeniz) Kıyısında Dağılım Gösteren Bazı Kahverengi Makroalg Türlerinin Biokimyasal İçerikleri

Özet

Bu çalışmada, İskenderun Körfezi (Kuzeydoğu Akdeniz) Kıyısından toplanan kahverengi makroalg türlerinin toplam protein, toplam karbonhidrat, toplam fenolik bileşik ve pigment içerikleri belirlendi. Toplamda sekiz kahverengi makroalg türünün (*Cystoseira barbata, Cystoseira corniculata, Cystoseira compressa, Dictyota dichotoma, Padina pavonia, Sargassum vulgare, Stypocaulon scoparium, Stypopodium schimperii*) analizleri yapıldı. En yüksek protein içeriği *S. schimperii* (65.19±4.32 mg g^{-1})'de elde edilirken, en düşük protein içeriği *C. compressa* (28.97±3.73 mg g^{-1}) bulunmuştur. Makroalglerin karbonhidrat konsantrasyonları 12.25±1.60 ile 47.92±5.66 mg g^{-1} arasında değişmiştir. En yüksek karbonhidrat konsantrasyonu D. *dichotoma* (47.92±5.66 mg g^{-1}) türünde kaydedilirken bunu 41.92±2.32 mg g^{-1} ile *S. schimperii* takip etmiştir. Makroalglerin toplam fenolik içerikleri 0.364±0.04 to 1.312±0.03 mg g^{-1}arasında olup, en yüksek fenolik içeriği 1.312±0.03 mg g^{-1} ile *S. schimperii* türünde belirlenmiştir. Aynı zamanda çalışılan kahverengi makrolagler arasında en yüksek klorofil-a ve karoten içeriği 4.09±0.60 ve 0.536±0.05 mg g^{-1} ile *S. schimperii* türünde tespit edilmiştir. Elde edilen bu

sonuçlara göre çalışılan kahverengi makroalg türleri (özellikle *S. schimperii*) gıda, farmakoloji ve kozmetik endüstrisinde potansiyel kaynak olarak kullanılabilir.

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