The determination of total protein, total soluble carbohydrate and pigment contents of some macroalgae collected from Gemlik-Karacaali (Bursa) and Erdek-Ormanlı (Balıkesir) in the Sea of Marmara, Turkey

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Abstract

In this study, 12 taxa from the *Chlorophyta*, *Phaeophyta* and *Rhodophyta* were collected from different depths at Gemlik-Karacaali and Erdek-Ormanlı. A total of 175 specimens from these divisions were used to determine Total Protein (TP), Total Soluble Carbohydrate (TSCH) and Chlorophyll *a* (Chl *a*), Chlorophyll *b* (Chl *b*), Chlorophyll *c* (Chl *c*), total carotenoid (Car) contents and Chl *b*/Chl *a*, Chl *c*/Chl *a*, Car/Chl *a*, Car/Chl *b*, Car/Chl *c* ratios. TP, TSCH and pigment contents varied significantly with respect to the algal taxa, stations and depth distribution. In addition, individual differences were important in all of the measured parameters.

The maximum TP contents (0.94%–31.03%) were determined in some of the *Rhodophyta*. In some green seaweeds belonging to the genus *Ulva* L., the TP content was determined between 2.9%–28.1%. Lower TP contents were determined in *Cystoseira barbata* (Good) C. Agardh (1.1%–4.3%). In contrast to TP contents,

TSCH values were very low; maximum TSCH were determined in *Ulva* species, as were protein contents. In conclusion, the variations in TP, TSCH and pigment in 12 taxa of macroalgae were analysed according to station, depth, and environment.

1. Introduction

In marine ecosystems, macroalgae are ecologically and biologically important. Macroalgal communities provide nutrition, reproduction, and an accommodating environment for other living organisms (Wahbeh 1997, Foster & Hodgson 1998, Fleurence 1999, Lindsey Zemke-White & Clements 1999, McClanahan et al. 2002, Wilson 2002). Because of these properties, macroalgae are some of the most important organisms maintaining the ecosystem's stability.

Macroalgal polysaccharides are used in the food, cosmetics, paint, crop, textile, paper, rubber and building industries. In addition, they are used in medicine and in pharmacology for their antimicrobial, antiviral, antitumor, anticoagulant and fibrinolytic properties (Round 1973, Chengkui & Junfu 1984, Fenical & Paul 1984, Vreeland et al. 1987, Cannell 1990, Güven et al. 1991, Parker 1993, Honya et al. 1994, Fleurence 1999, Fleurence et al. 1999). According to FAO (Food and Agriculture Organisation), the annual global aquaculture production of marine algae is 6.5×10^6 tonnes (Fleurence 1999). In Turkey, macroalgae are not cultured for nutrition, and commercial harvesting is rare. An exceptional instance of this situation concerns the red algae species *Gracilaria verrucosa* (Hudson) Papenfuss, which was harvested from İzmit Bay for export to Japan in 1990–1991 (Yenigül 1993).

Macroalgae have been harvested for a long time in the Far East, where they are used in the food industry. Because of their high protein content, Protein Concentrates (PCs) of seaweeds have become more important for the food industry, especially in developed countries (Wong & P Cheung 2001). Their recent utilisation as an animal feed is on the increase. The use of macroalgae as food for fish larvae has been initiated as an alternative to microalgal cultures. In consequence, the nutritional content of microalgae is being investigated with a view to their being utilised as animal feed (Wahbeh 1997, Foster & Hodgson 1998, Lindsey Zemke-White & Clements 1999).

Even though Turkey is surrounded by seas on three sides, the macroalgal industry is as yet undeveloped. Therefore, it has not been possible to profit from the many marine algae that are ready to be harvested. First, macroalgal productivity and contents have to be analysed in order to determine how to profit from them. Though widespread on Mediterranean, Aegean and Black Sea shores, brown, red and green seaweeds have been studied only in a limited number of articles (Güner 1970, Güner & Aysel 1978, Aysel & Güner 1980, Öztürk 1988, 1993,

1996, Aysel 1989, 1997a, b, Dural 1989, 1990, Dural et al. 1989, Aysel et al. 1996, 2000, Öztürk et al. 1996, Turna et al. 2000). Some biochemical investigations on economically important species have been carried out (Çetingül et al. 1994, Çetingül & Güner 1996, Çetingül et al. 1996, Ertan & Ateş 1996/97, Ertan et al. 1996/97, Çetingül & Aysel 1998). Although the distribution of macroalgae in the Sea of Marmara has been determined (Aysel et al. 2002, Erduğan et al. 2002, Okudan et al. 2002), no study of their chemical content has yet been done.

The quantity of macroalgal pigment is mostly used to define algal biomass. It is also affected by environmental factors. Many studies indicate that extreme environmental factors, e.g. salinity, temperature, nutrients, and intense irradiance, cause a high rate of pigment production (Marin et al. 1998, Boussiba et al. 1999, Zucchi & Necchi 2001).

The aim of this study is to determine the Total Soluble Carbohydrates (TSCH), Total Protein (TP) and pigment contents of some macroalgae, which were collected from various depths in Gemlik Bay-Karacaali and off the Kapıdağ Peninsula-Ormanlı in the Sea of Marmara.

2. Materials and methods

The Sea of Marmara (11.474 km^2), which is located in northwestern Turkey, is an inland sea, between Europe in the North and Asia in the South. 280 km long and 80 km wide, it is connected in the east with the Black Sea through the Bosphorus (İstanbul Bosphorus) and in the west with the Aegean Sea, part of the Mediterranean Sea, through the Dardanelles (Çanakkale Bosphorus). Its greatest depth is 1389 m (Fig. 1).

Uludağ University Underwater Community (USAT) took macroalgae from three different depths in Gemlik Bay-Karacaali and Kapıdağ Peninsula-Ormanlı in the Sea of Marmara by means of SCUBA diving. Dry and aqueous herbaria were made to identify the macroalgae and were taken to the laboratory in stable heated picnic – type containers. In the laboratory, they were cleaned, washed with distilled water and dried at 55°C to constant weight. The samples were fixed with 2% formaldehyde solution and identified taxonomically (Feldmann 1937, Fritsch 1945, 1971, Chadefaud & Emberger 1960, Bliding 1963, and Hommersand 1963).

The seaweeds were taken from three different depths: the surface layer (0–0.5 m), 5 m and 10 m on 19 May 2001 from Kapıdağ Peninsula-Ormanlı, and on 2 June 2001 from Gemlik Bay-Karacaali. Three divisions of seaweeds were identified: *Chlorophyta* – *Ulva lactuca* L., *U. rigida* (C. Agardh) Thur., *Enteromorpha intestinalis* (L.) Link, *E. compressa* (L.) Grev., *E. clathrata* (Roth) Grev., *E. linza* (L.) J. Agardh., *Codium* sp. and *Codium*

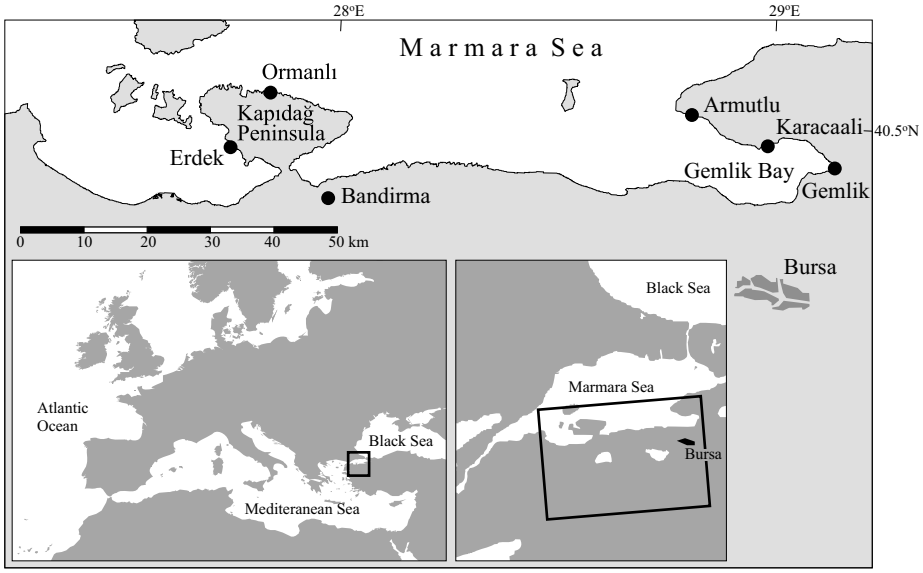

Fig. 1. Sampling stations (Ormanlı and Karacaali) in the Sea of Marmara

tomentosum (Huds.) Sets.; *Phaeophyta* – *Cystoseira barbata* (Good) C. Agardh; *Rhodophyta* – *G. verrucosa* (Huds.) Papenfuss, *Ceramium* sp., and *Polysiphonia* sp.

A total of 175 specimens from these divisions were used to determine Total Protein (TP), Total Soluble Carbohydrate (TSCH) and Chlorophyll *a* (Chl *a*), Chlorophyll *b* (Chl *b*), Chlorophyll *c* (Chl *c*), Total Carotenoid (Car) contents and Chl *b*/Chl *a*, Chl *c*/Chl *a*, Car/Chl *a*, Car/Chl *b*, Car/Chl *c* ratios. TP contents were determined by the Bradford method (1976), TSCH contents by the Anthron method (Carroll et al. 1956) as g kg^{-1} d.w. (dry weight) Chl *a* and Chl *b* contents for *Chlorophyta* were determined in accordance with the Jeffrey & Humphrey method (1975) with 90% acetone as solvent. Chl *a* and Chl *c* in *Phaeophyta* (Seely et al. 1972) and Chl *a* in *Rhodophyta* (Seely et al. 1972) were determined by dimethylsulphoxide (DMSO) extraction and calculated as mg g^{-1} f.w. (fresh weight). For all divisions 'Car' was determined according to Parsons & Strickland's (1963) method with 90% acetone.

Statistical analysis was performed using the SPSS for Windows V10 computer statistics program. All data displayed a normal distribution. The results were given as a mean with standard deviation ($\pm$ SD). Pearson correlation analyses were used to determine relationships between variables. The non-parametric Mann-Whitney's U-test was applied because the numbers of samples were not equal. The value of α was 0.05 using two-tailed tests throughout.

3. Results

A total of 175 specimens belonging to 12 taxa were used to determine pigments, TSCH and TP contents (Tables 1 and 2). All the parameters from the Karacaali and Ormanlı stations are compared in Figs. 2–6. The number of samples (n) of the 12 taxa is given in these tables. The statistical data are set out in Tables 3 and 4.

As a result, TSCH and TP contents in the macroalgae were determined and highly individual differences were defined. The highest average TSCH in the *U. rigida* (*Chlorophyta*) was 63.04 ± 29.15 g kg^{-1} d.w. (6.3%) taken from 10 m at Ormanlı (Table 2, Fig. 6a), while the lowest value was recorded in *Codium* sp. 6.45 ± 2.81 (0.65% sampled from 5 m depth at Karacaali) (Table 1, Fig. 4). The average TSCH of *Enteromorpha* sp. at Karacaali varied between 10.1 ± 7.13 g kg^{-1} d.w. (1.01%) and 24.2 ± 2.8 g kg^{-1} d.w. (2.42%). The lowest average value was found in *E. clathrata*, the highest average in *E. linza* (Table 1, Fig. 2).

During the study, *G. verrucosa* (*Rhodophyta*) was collected from the Karacaali station. In addition, *Polysiphonia* sp. and *Ceramium* sp. were gathered at Ormanlı. In this division, the highest TSCH content was determined to be 43.07 ± 13.82 g kg^{-1} d.w. (4.3%) (Table 1, Fig. 2) in *G. verrucosa* at the surface (Karacaali), the lowest in *Ceramium* sp. 2.28 ± 0.71 g kg^{-1} d.w. (0.23%) at the surface (Ormanlı) (Table 2, Fig. 2). During the study, the lowest TSCH values were determined in *Ceramium* sp. (*Rhodophyta*). This was the lowest average TSCH value in all the divisions. In the *Phaeophyta* division, only *C. barbata* was taken from Ormanlı, the average TSCH content being 9.09 ± 1.41 g kg^{-1} at the surface, and 8.98 ± 1.24 g kg^{-1} at 5 m depth (Table 2, Figs. 2 and 4).

There was a depth-dependent decrease in TSCH in *Ulva* spp. taken from Karacaali. This decrease was not significant in *U. rigida*, but it was in *U. lactuca* (Table 3). Although an increase in TSCH occurred at 10 m in *U. rigida*, this increase was not significant (Table 3). *U. lactuca* collected from Ormanlı displayed significant variation according to depth (Table 3). In addition, *C. tomentosum* showed significant variation depending on depth (Table 3). However, a depth-dependent though statistically insignificant decrease in TSCH was recorded in *C. barbata* at Ormanlı (Table 3).

The highest average values of TP were determined in *U. rigida* (280.67 ± 124 g kg^{-1} d.w. (28.1%)) and *U. lactuca* (277.58 ± 135 g kg^{-1} d.w. (27.8%)) sampled from the surface at Karacaali station (Table 1, Fig. 2). During the study, *U. rigida* from 5 m depth at Karacaali had a TP of 28.9 ± 33.19 g kg^{-1} d.w. (2.89%), the lowest value of all (Table 1, Fig. 4).

The highest TP content among the *Rhodophyta* (310.25 ± 168.4 g kg^{-1} d.w. (31.03%)) was determined in the *Polysiphonia* sp. taken from

Table 1. The chemical composition of some macroalgae collected from Karacaali

Taxa		TSCH [g kg^{-1} d.w.]	TP [g kg^{-1} d.w.]	Chl *a* [mg g^{-1} f.w.]	Chl *b* [mg g^{-1} f.w.]	Car [mg g^{-1} f.w.]	Chl *b*/Chl *a*	Car/Chl *a*	Car/Chl *b*
		Mean ± SD							
E. linza (n:4)	surface	24.20 ± 2.80	75.70 ± 24.64	0.79 ± 0.57	0.57 ± 0.43	0.18 ± 0.17	0.65 ± 0.24	0.19 ± 0.09	0.28 ± 0.09
E. intestinalis (n:11)	surface	18.97 ± 5.39	56.55 ± 25.25	0.41 ± 0.20	0.34 ± 0.16	0.11 ± 0.07	0.86 ± 0.44	0.26 ± 0.12	0.31 ± 0.14
E. clathrata (n:21)	surface	10.10 ± 7.13	164.69 ± 102	0.55 ± 0.12	0.24 ± 0.08	0.11 ± 0.06	0.44 ± 0.11	0.19 ± 0.07	0.44 ± 0.11
E. compressa (n:4)	surface	16.09 ± 9.64	82.0 ± 6.98	0.40 ± 0.19	0.31 ± 0.26	0.08 ± 0.06	0.69 ± 0.29	0.18 ± 0.06	0.27 ± 0.02
U. lactuca (n:12)	surface	28.59 ± 7.13	277.58 ± 135	0.39 ± 0.32	0.29 ± 0.20	0.08 ± 0.05	0.84 ± 0.30	0.22 ± 0.05	0.28 ± 0.07
U. lactuca (n:3)	5 m	16.43 ± 1.09	78.57 ± 75.39	0.22 ± 0.09	0.21 ± 0.05	0.05 ± 0.02	0.98 ± 0.21	0.22 ± 0.04	0.23 ± 0.03
U. rigida (n:9)	surface	25.80 ± 6.57	280.67 ± 124	0.18 ± 0.28	0.15 ± 0.26	0.05 ± 0.08	0.89 ± 0.44	0.29 ± 0.12	0.35 ± 0.12
U. rigida (n:4)	5 m	14.47 ± 6.90	28.9 ± 33.19	0.14 ± 0.15	0.16 ± 0.12	0.17 ± 0.27	1.41 ± 0.35	2.66 ± 4.80	1.68 ± 2.98
Codium sp. (n:4)	5 m	6.45 ± 2.81	73.18 ± 41.05	0.02 ± 0.01	0.12 ± 0.19	0.03 ± 0.05	1.48 ± 0.26	0.37 ± 0.10	0.25 ± 0.03
G. verrucosa (n:22)	surface	43.07 ± 13.82	9.40 ± 1.65	0.16 ± 0.10	–	0.01 ± 0.02	–	0.04 ± 0.02	–

Table 2. The chemical composition of some macroalgae collected from Ormanlı

Taxa		TSCH [g kg^{-1} d.w.]	TP [g kg^{-1} d.w.]	Chl *a* [mg g^{-1} f.w.]	Chl *b* [mg g^{-1} f.w.]	Car [mg g^{-1} f.w.]	Chl *b*/Chl *a*	Car/Chl *a*	Car/Chl *b*
		Mean ± SD							
Polysiphonia sp. (n:4)	surface	19.44 ± 1.06	310.25 ± 168.4	0.71 ± 0.22	–	0.06 ± 0.04	–	0.08 ± 0.06	–
Ceramium sp. (n:8)	surface	2.28 ± 0.71	254.9 ± 169.05	0.90 ± 0.23	–	0.02 ± 0.01	–	0.02 ± 0.01	–
U. rigida (n:4)	5 m	41.93 ± 29.94	64.45 ± 27.9	0.11 ± 0.003	0.07 ± 0.02	0.04 ± 0.04	0.59 ± 0.02	0.13 ± 0.05	0.22 ± 0.08
U. rigida (n:7)	10 m	63.04 ± 29.15	50.67 ± 16.28	0.09 ± 0.05	0.06 ± 0.03	0.01 ± 0.01	0.79 ± 0.44	0.18 ± 0.14	0.24 ± 0.19
C. tomentosum (n:12)	5 m	33.40 ± 38.55	78.12 ± 25.73	0.06 ± 0.02	0.04 ± 0.01	0.01 ± 0.005	0.61 ± 0.11	0.17 ± 0.057	0.24 ± 0.11
C. tomentosum (n:16)	10 m	43.69 ± 12.18	78.27 ± 19.56	0.06 ± 0.01	0.07 ± 0.08	0.01 ± 0.01	0.72 ± 0.08	0.22 ± 0.08	0.31 ± 0.10
Taxa		TSCH [g kg^{-1} d.w.]	TP [g kg^{-1} d.w.]	Chl *a* [mg g^{-1} f.w.]	Chl *c* [mg g^{-1} f.w.]	Car [mg g^{-1} f.w.]	Chl *c*/Chl *a*	Car/Chl *a*	Car/Chl *c*
		Mean ± SD							
C. barbata (n:17)	surface	9.09 ± 1.41	10.49 ± 6.15	1.53 ± 0.43	0.73 ± 0.90	0.02 ± 0.01	0.47 ± 0.45	0.03 ± 0.05	0.06 ± 0.07
C. barbata (n:13)	5 m	8.98 ± 1.24	43.11 ± 21.36	0.71 ± 0.32	0.34 ± 0.43	0.01 ± 0.001	0.79 ± 1.50	0.01 ± 0.01	0.04 ± 0.05

Table 3. Mann-Whitney U-Test comparison between groups according to depth and station

Chlorophyta comparison **Karacaali station**		TP	TSCH	Chl *a*	Chl *b*	Car	Chl *b*/Chl *a*	Car/Chl *a*	Car/Chl *b*
U. lactuca (surface-5 m)	z	–2.458	–2.6						
	(*P*)	(0.014)	(0.009)	NS	NS	NS	NS	NS	NS
U. rigida (surface-5 m)	z	–2.781							
	(*P*)	(0.005)	NS	NS	NS	NS	NS	NS	NS
Ormanlı station									
U. rigida (5 m–10 m)	z (*P*)	NS	NS	NS	NS	NS	NS	NS	NS
C. tomentosum (5 m–10 m)	z		–3.343		–2.186		–3.088		
	(*P*)	NS	(0.001)	NS	(0.029)	NS	(0.002)	NS	NS
5 m depth									
U. rigida (Karacaali-Ormanlı)	z	–2.309					–2.323	–2.021	
	(*P*)	(0.021)	NS	NS	NS	NS	(0.020)	(0.043)	NS
Phaeophyta comparison **Ormanlı station**		TP	TSCH	Chl *a*	Chl *c*	Car	Chl *c*/Chl *a*	Car/Chl *a*	Car/Chl *c*
C. barbata (surface-5 m)	z	–4.215		–4.21	–2.893	–2.024			
	(*P*)	(0.000)	NS	(0.000)	(0.004)	(0.043)	NS	NS	NS

NS – not significant; each number of samples (n) was given in Table 1 and 2.

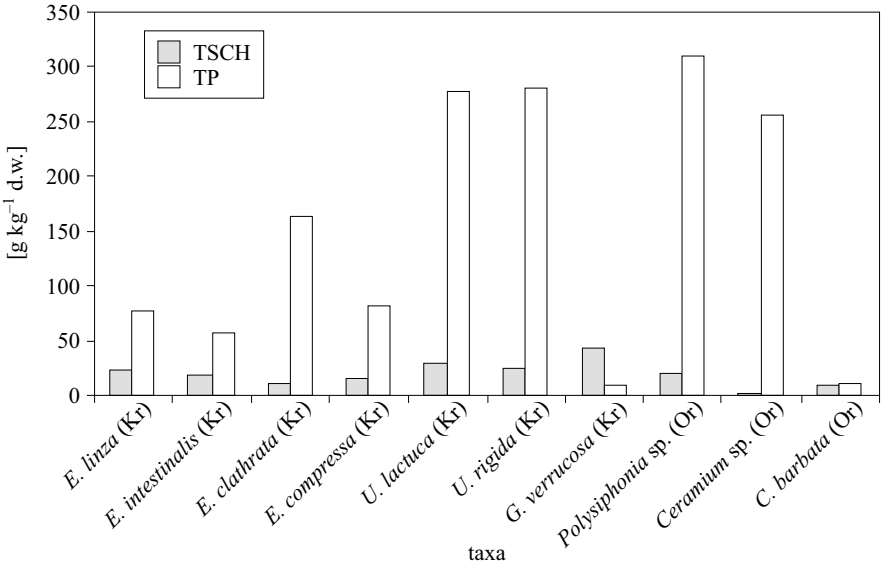

Fig. 2. The change in TSCH and TP levels in a number of taxa collected from surface waters at Ormanlı and Karacaali stations. Kr = Karacaali, Or = Ormanlı

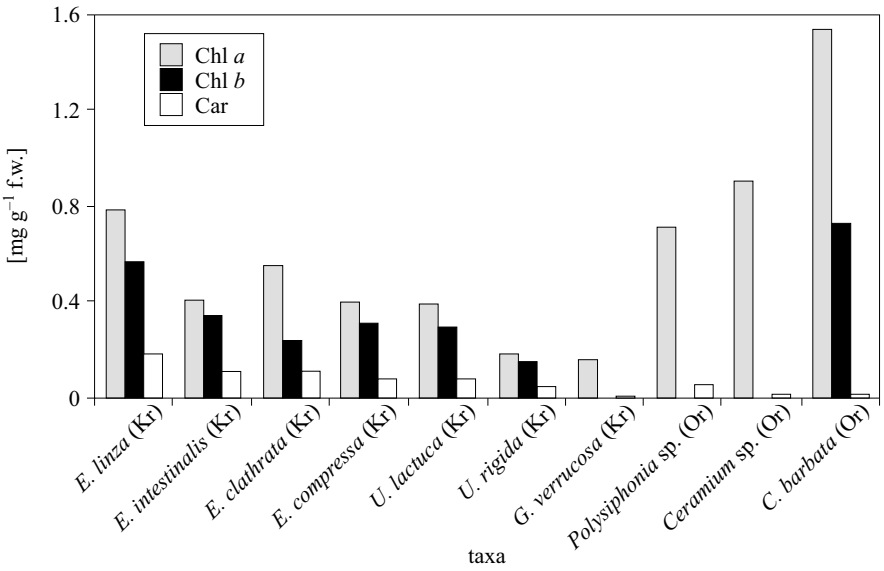

Fig. 3. The change in Chl *a*, Chl *b* and Car levels in a number of taxa collected from surface waters at Ormanlı and Karacaali stations. Kr = Karacaali, Or = Ormanlı

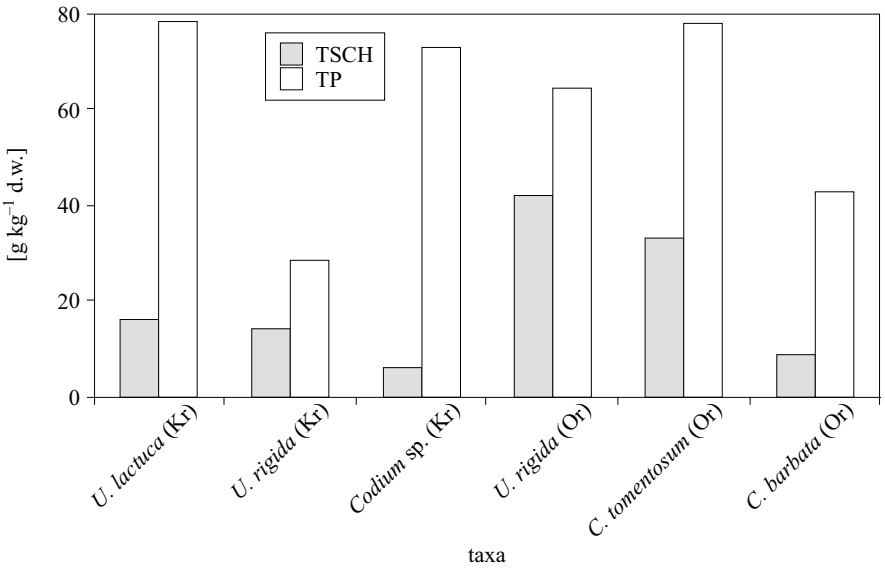

Fig. 4. The change in TSCH and TP levels in a number of taxa collected from surface waters at Ormanlı and Karacaali stations. Kr = Karacaali, Or = Ormanlı

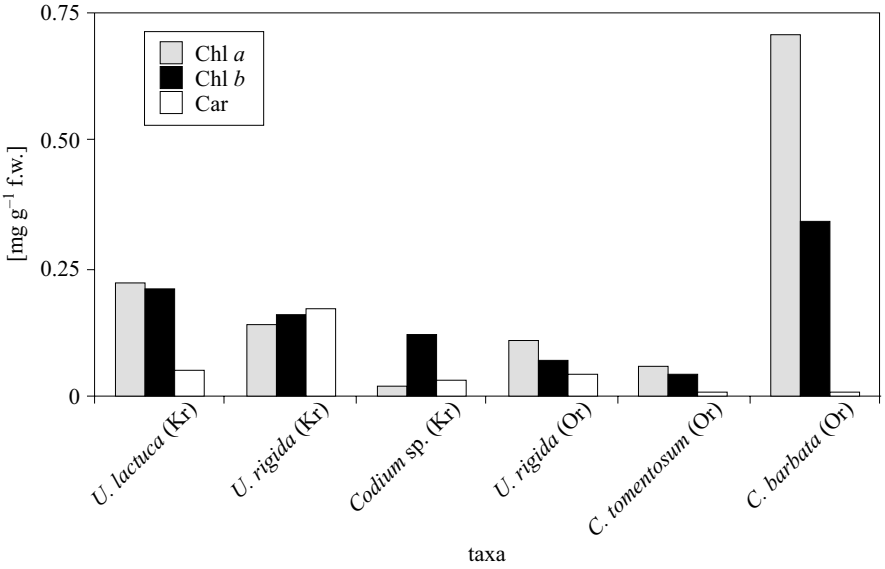

Fig. 5. The change in Chl *a*, Chl *b* and Car levels in a number of taxa collected from surface waters at Ormanlı and Karacaali stations. Kr = Karacaali, Or = Ormanlı

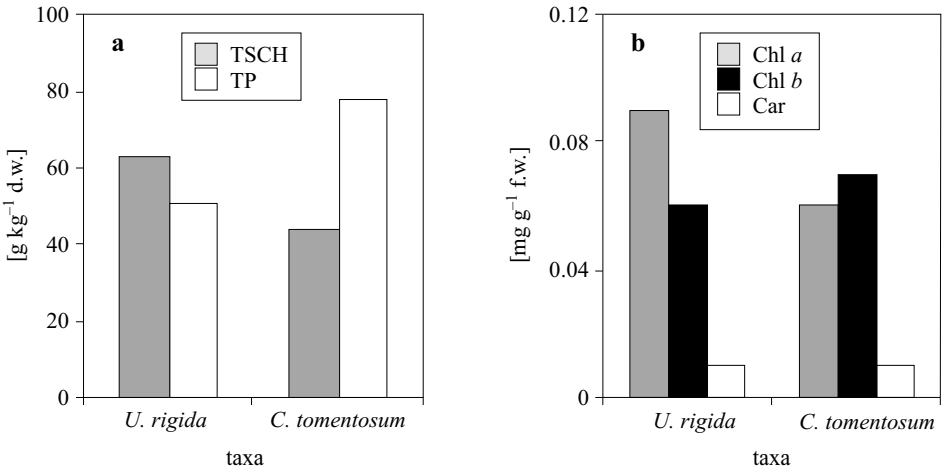

Fig. 6. The change in TSCH and TP levels in a number of taxa collected from a depth 10 m at Ormanlı station (a). The change in Chl *a*, Chl *b* and Car levels in a number of taxa collected from a depth 10 m at Ormanlı station (b)

the surface at Ormanlı; this was the highest TP content in the entire study (Table 2, Fig. 2). The lowest TP content in this division was 9.40 ± 1.65 g kg^{-1} d.w. (0.94%) in *G. verrucosa* from the surface at Karacaali. *C. barbata* was the only species from the *Phaeophyta*; its TP was determined to be 10.49 ± 6.15 g kg^{-1} d.w. (1.1%) at the surface and 43.11 ± 21.36 g kg^{-1} d.w. (4.3%) at 5 m depth.

In all *Ulva* spp. (*Chlorophyta*) except *U. rigida* TP decreased significantly from c. 1/5 to 10 times according to depth at Ormanlı (Table 3). However, in *C. tomentosum* from Ormanlı, there was no depth-dependent variation (Tables 2 and 3, Figs. 4 and 6a). In *C. barbata* from Ormanlı the TP content increased significantly by a factor of 4 from the surface to 5 m depth (Tables 2 and 3, Figs. 2 and 4).

Like TSCH and TP, the quantities of pigment in macroalgae also displayed considerable individual differences. In the members of the *Chlorophyta* the highest Chl *a*, Chl *b* and Car contents were 0.79 ± 0.57 mg g^{-1} f.w., 0.57 ± 0.43 mg g^{-1} f.w. and 0.18 ± 0.17 mg g^{-1} f.w. respectively at the surface at Karacaali in *E. linza*. The lowest Chl *a* value at the same station was 0.02 ± 0.01 mg g^{-1} f.w. in the *Codium* spp. (Table 1, Fig. 3). The lowest Chl *b* and Car values were 0.04 ± 0.01 mg g^{-1} f.w. and 0.01 ± 0.005 mg g^{-1} f.w. respectively in *C. tomentosum* from 5 m depth at Ormanlı (Table 2, Fig. 5).

The highest Chl *a* and Car values in *Polysiphonia* sp. (*Rhodophyta*) from the surface layer at Ormanlı were 0.71 ± 0.22 mg g^{-1} f.w. and 0.06 ± 0.04 mg g^{-1} f.w. respectively. The lowest values were 0.16 ± 0.1 and

0.01 ± 0.02 mg g^{-1} f.w. in *G. verrucosa* from the surface layer at Karacaali. The average Chl *a*, Chl *c* and Car values in *C. barbata* (*Phaeophyta*) were 1.53 ± 0.41, 0.73 ± 0.90 and 0.02 ± 0.01 mg g^{-1} f.w. for surface samples, and 0.71 ± 0.32, 0.34 ± 0.43 and 0.01 ± 0.001 mg g^{-1} f.w. for the 5 m samples.

While Chl *a*, Chl *b* and Car values decreased in *U. rigida* from Ormanlı and *U. lactuca* from Karacaali with increasing depth, Chl *a* decreased in *U. rigida* at Karacaali. On the other hand, Chl *b* and Car values increased. However, no significant variation was determined (Table 3). For *C. tomentosum*, though Chl *a* and Car values were constant, Chl *b* increased significantly (Table 3). In addition, the Chl *a*, Chl *c* and Car values in *C. barbata* (*Phaeophyta*) all significantly decreased with depth (Table 3).

In the *Chlorophyta* the highest Chl *b*/Chl *a* ratio was 1.48 ± 0.26 mg g^{-1} f.w. for *Codium* sp. at Karacaali at a depth of 5 m and 1.41 ± 0.35 mg g^{-1} f.w. for *U. rigida*. The lowest rate was determined at 0.44 ± 0.11 mg g^{-1} f.w. in *E. clathrata* from the same station in the surface layer. Even though the highest Car/Chl *a* and Car/Chl *b* ratios were found to be 2.66 ± 4.8 and 1.68 ± 2.98 mg g^{-1} f.w. in *U. rigida* from Karacaali at a depth of 5 m, the lowest values were 0.13 ± 0.05 and 0.22 ± 0.08 mg g^{-1} f.w. in *U. rigida* at Ormanlı from a depth of 5 m (Tables 1 and 2).

In *Rhodophyta*, the highest Car/Chl *a* ratio was 0.08 ± 0.06 mg g^{-1} f.w. for *Polysiphonia* sp. taken from the surface at Karacaali, whereas the lowest ratio was 0.02 ± 0.01 mg g^{-1} f.w. in *Ceramium* sp. at the surface at Ormanlı. The Chl *c*/Chl *a* and Car/Chl *c* ratios for *C. barbata* (*Phaeophyta*) from the surface level and 5 m depth are given in Table 2. With increasing depth, Chl *b*/Chl *a*, Car/Chl *a* and Car/Chl *b* ratios in *U. rigida* and *C. tomentosum* increased. In *U. lactuca* the ratio of Chl *b*/Chl *a* increased but Car/Chl *b* decreased. The Car/Chl *a* ratios remained constant (Tables 1 and 2). However, variation was significant only in the Chl *b*/Chl *a* ratio in *C. tomentosum* (Table 3).

U. rigida was the only taxon collected from Ormanlı and Karacaali at the same depth (5 m). There were significant variations in TP and some pigment ratios between the two stations (Table 3).

Correlation analysis was performed in order to define the relationship between the amount of pigment, TSCH and TP in individual species. In addition, only in *E. intestinalis* was a correlation defined between the TP content and Chl *a* (0.672 $P<0.05$). However, in some taxa significant correlations were found between accessory pigments and Chl *a*. These correlations are given in Table 4.

Table 4. Relationships between accessory pigments and chlorophyll *a*

	E. lingulata-surface[a]			*E. intestinalis*-surface[a]			*U. rigida*-surface[a]		
	Chl *a*	Chl *b*	Car	Chl *a*	Chl *b*	Car	Chl *a*	Chl *b*	Car
Chl *a*	1	0.71*	0.699**	1	0.849**	0.82**	1	0.997**	0.998**
Chl *b*	–	1	0.757**	–	1	0.999**	–	1	0.999**
Car	–	–	1	–	–	1	–	–	1
	U. lactuca-surface[a]			*C. tomentosum* 5 m[b]			*C. tomentosum* 10 m[b]		
	Chl *a*	Chl *b*	Car	Chl *a*	Chl *b*	Car	Chl *a*	Chl *b*	Car
Chl *a*	1	0.831**	0.923**	1	0.97**	0.811**	1	NS	0.678**
Chl *b*	–	1	0.966**	–	1	0.715**	–	1	NS
Car	–	–	1	–	–	1	–	–	1

* $P < 0.05$, ** $P < 0.01$, NS – not significant, [a] Karacaali station, [b] Ormanlı station.

4. Discussion

The study determined pigment in macroalgae, TP and TSCH contents, which varied depending on the species, and there were some noticeable interspecific differences. Many researchers have reached the same conclusion, finding that the nutritional contents of macroalgae depend not only on season and geography (Fleurence 1999, Fleurence et al. 1999, Haroon et al. 2000), but also on the nutrient content of the environment (Marin et al. 1998). Moreover, Zucchi & Necchi (2001) determined that physical factors, such as light density and quality, photoperiod and temperature, can alter pigment contents. In addition, Muthuvelan et al. (1997/98) stated that Chl *a*, Chl *b* and TP contents indicated an increase in white light in an *Ulva* species.

In this study, the highest TP contents were determined in *Polysiphonia* sp. and *Ceramium* sp. (*Rhodophyta*) (25.5%–31%); they were the lowest in *G. verrucosa* (*Rhodophyta*) (0.94%), and in *C. barbata* (*Phaeophyta*) (1.1%–4.3%). According to Fleurence et al. (1999), Fujiwara-Arasaki et al. and Morgan et al. emphasised the highest TP content in *Rhodophyta* (35%–47%) and stated that the lowest TP content was in Phaeophyta (5%–10%). In addition to the highest TP content found in *Rhodophyta*, Eswaran et al. (2002) determined the TP content in the *Gracilaria* species as varying between 3.9 and 1.07 g kg^{-1} d.w. (0.39%–0.1%). This shows similarities to our study.

The lowest TP amounts (0.94%) in *Rhodophyta* were determined in *G. verrucosa*. Moreover, Rouxel et al. (2001) observed that the protein content of *G. verrucosa* showed some variations according to season, and

they found that the TP content declined approximately threefold from April to June. This may be the reason for the low TP quantities.

As far as the *Chlorophyta* are concerned, the highest TSCH and TP contents were determined in the *Ulva* species from the Karacaali surface level (6.3% and 28.1% respectively). Regarding TP contents in *Enteromorpha* species, the highest content was found to be 16.5% in *E. clathrata*, although in other *Enteromorpha* species the TP contents varied between 5.6% and 8.2%. The highest TSCH was 2%–4% in *E. linza*. In the other *Enteromorpha* species, the TSCH was less than 1.9%. In *Codium* sp. and *C. tomentosum* TSCH and TP were fairly low (Tables 1 and 2). According to previous studies, the highest nutritional contents were found in the *Chlorophyta*. Mathers & Montgomery (1997) found that the TP content in *Enteromorpha* varies between 16.04% and 16.14%, moreover that the TSCH content varies between 2.42% and 2.54%, values that are in agreement with the results of this study. By contrast, Haroon et al. (2000) found the major component in *Enteromorpha* spp. to be TSCH. Mathers & Montgomery (1997) also found TP contents in *U. lactuca* to lie between 19.29% and 18.22%, TSCH contents between 3.22% and 2.26%, whereas Fleurence et al. (1999) found the TP content of *Ulva* spp. to vary between 18% and 26%. According to the present study, the TP content in *Ulva* spp. was quite high in Karacaali. *Ulva* spp. and *Enteromorpha* spp. (*Chlorophyta*) were regarded as ruderal plants capable of maturing in polluted waters. It is important to note that even though no chemical analysis of the water was done, *Ulva* spp. and *Enteromorpha* spp. were in abundance at Karacaali station (Gemlik Bay) because of the pollution. In addition, since the water at the Ormanlı station was cleaner, *Rhodophyta* and *Phaeophyta* were prevalent. In one of their studies, Aysel & Güner (1979) established *G. verrucosa* as growing well in polluted water, just as we found in Gemlik Bay. The studies of Erdugan et al. (2002) established that the members of the *Ulvales* increased around Bursa shores where the seawater was polluted by organic and inorganic wastes. While Erdugan et al. (2002) determined the R/F (Rhodophyta/Phaeophyta) rate as 2.25 on Bursa shores, Aysel et al. (2002) calculated a value of 2.088 at Balıkesir. Therefore, organic and inorganic pollution has not yet been defined as life-threatening on the Bursa and Balıkesir shores. On the other hand, the low R/H ratio at Bursa shows that Gemlik Bay (Bursa) is dirtier than the Kapıdağ Peninsula (Balıkesir).

When macroalgae from the Karacaali and Ormanlı stations were compared, variations in the TP and TSCH quantities indicated large differences that depend on the relevant division of algae, depth and stations (Table 3). Significant variations were observed in TP in all

taxa with depth (Table 3). Çetingül & Güner (1996) found that TP of *U. rigida* and *E. linza* indicated important station-dependent variations on stations. It can therefore be concluded that the environmental, seasonal and physicochemical properties of the seawater are the most important factors affecting the algae. Pinchetti et al. (1998) explained that the green macroalga *Ulva* has been widely used as a biofilter because of its high efficiency in the removal of nitrogenous inorganic compounds. On the other hand, Brix et al. determined *Ulva* spp. to be indicator organisms (Malea & Horritonidis 2000). When annual TP quantities were compared, Çetingül & Güner (1996) stated that the TP contents of algae which flourished in severely and moderately polluted water were higher than those of clean water algae.

In this study, at two different depths, different changes were seen for both accessory pigments and Chl *a* in *C. tomentosum* and *C. barbata* according to depth (Table 3). Darley (1982) also emphasised this point of view. In some taxa, positive correlations were found between accessory pigments and Chl *a* (Table 4). In our study, there was a significant increase in the Chl *b*/Chl *a* ratio in *U. rigida*, and *C. tomentosum* from the surface to the bottom. Darley (1982) stressed that the Chl *b*/Chl *a* ratio of green algae also increased slightly with depth.

In conclusion, the variations in TP, TSCH and pigment were determined in 12 taxa of macroalgae according to station, depth, and environment. Hence, the TP-rich *Ulva* and *Enteromorpha* species in Turkish seashores can easily be used in the food industry for nutritional purposes.

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