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Gross chemical composition of three common macroalgae and a sea grass on the Pacific coast of Baja California, Mexico

Composición química gruesa de tres macroalgas y un pasto marino en la costa del Pacífico de Baja California, México

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ABSTRACT

Chemical composition (moisture, crude protein, crude fibre, ether extractables, ash, and nitrogen-free extract) was determined in three marine algae and one sea grass of the Pacific coast of Baja California Sur. Samples of *Eisenia arborea, Macrocystis pyrifera, Gelidium robustum,* and *Phyllospadix torreyi* from natural populations were evaluated in October 1995, and January, May, and August 1996. Nitrogen-free extract, mainly carbohydrates, was the most important constituent in all species, followed by ash, protein, crude fibre, and ether extractables (mainly lipids) in brown algae species. In red algae, protein content was higher than ash. Sea grass *(P. torreyi)* had high crude fibre, followed by ash, protein, and ether extractables.

Key words: Chemical composition, seaweed, *Macrocystis, Eisenia, Gelidium, Phyllospadix.*

RESUMEN

Se determinó la composición química (humedad, proteina cruda, fibra cruda, extracto etéreo, cenizas y extracto libre de nitrógeno) en tres macroalgas marinas y un pasto marino abundantes en las costas del Pacífico de Baja California Sur. Poblaciones naturales de *Eisenia arborea, Macrocystis pyrifera, Gelidium robustum* y *Phyllospadix torreyi* fueron muestreadas en Octubre 1995 y en Enero, Mayo y Agosto de 1996. El extracto libre de nitrógeno, principalmente carbohidratos, fue el constituyente de mayor proporción en las especies estudiadas. En algas pardas, y en orden decreciente le siguen a los carbohidratos, cenizas, proteina cruda, fibra cruda y extracto etéreo (principalmente lípidos). En algas rojas, el contenido de proteina cruda fue mayor que el de cenizas. En contraste, en el pasto marino *(P. torreyi)* se obtuvieron valores altos de fibra cruda, seguidos de cenizas, proteina cruda y extracto etéreo.

Palabras clave: Composición química, algas marinas, *Macrocystis, Eisenia, Gelidium, Phyllospadix.*

INTRODUCTION

Along the Pacific coast of Baja California, commercially valuable species of seaweed have been analysed for chemical composition. These include the green alga *Ulva lactuca* Linnaeus (Castro *et al.*, 1994a), brown alga *Macrocystis pyrifera* (Linnaeus) C. Agardh (Manzano and Rosales 1989; Rodríguez-Montesinos and Hernández-Carmona 1991; Castro *et al.*,1994b), *Sargassum sinicola* Setchell and Gardner (Manzano and Rosales, 1989), and *Sargasum* spp. (Pérez, 1997), and red alga *Chondracanthus canaliculatus* (Harvey) Guiry (Ballesteros *et al.* 1990 and 1991). Geographical and seasonal variations in chemical composition were shown. Even though relative proportions of the main constituents were more or less constant, maximum and minimum values changed seasonally according to environmental conditions at different sites (Rodríguez-Montesinos and Hernández-Carmona, 1991).

There are few studies about seasonal influence on chemical composition of ecologically important seaweed and sea grass that play an important role in near-shore marine ecosystems as food, habitat, or refuge for many species of molluscs, crustaceans, and fish (Manzano and Rosales, 1989; Rodríguez and Hernández, 1991; Castro *et al.*, 1994b). Frequently, the most economically valuable seaweed species are those that are most ecologically important. Such is the case for the brown algae *M. pyrifera*, which is valued for its exceptionally large size and occurrence in dense monocultures (Foster and Schiel, 1985). This study measured seasonal changes in the chemical composition of three marine macroalgae and one sea grass common in benthonic environments along the Pacific coast of the Baja California Peninsula.

The main macroalgae of benthonic environments on the western coast of Baja California are brown algae *M. pyrifera*, *Eisenia arborea* Areschoug, and other Laminariales, red algae *Gelidium* spp., *Acrosorium* spp., and *Plocamium* spp., articulated coralline algae *Bossiella* spp. and *Corallina* spp., crustose coralline algae *Lithothamnium* spp. and *Lithophyllum* spp., and sea grass *Phyllospadix torreyi* S. Watson (Dawson *et al.*, 1960; Guzmán del Próo *et al.* ,1972 and 1991; Mateo-Cid and Mendoza-González, 1994). The organic matter and chemically bound energy produced by seaweed enters food webs either directly by grazing, or indirectly by production of organic detritus or dissolved organic matter. It has been suggested that these seaweed species support the main gastropod grazers in the community, including *Tegula eiseni* Jordan, *Tegula aureotincta* Forbes, *Ocenebra foveolata* Hinds, *Haliotis* spp., and *Megastraea undosa* Wood (Guzmán del Próo *et al.*, 1991).

In spite of commercial potential for seaweed harvest along the Baja California coast, only a few species are used as food for farmed organisms, as for the case of abalone. In regional hatcheries, the greatest portion of feed for abalone is harvested *Macrocystis pyrifera* (McBride, 1998). There are few experimental assays on growth of organisms fed with common species (Serviere-Zaragoza et al., 1998 and 2001). In contrast, common local seaweeds have been evaluated and used extensively in abalone aquaculture in other coastal areas of the world (Uki *et al.*, 1986; Shepherd and Steinberg, 1992; Corazani and Illanes, 1998; Simpson and Cook, 1998).

MATERIAL AND METHODS

Samples of marine plants were obtained from two locations along the coast of Baja California Sur during October 1995, and January, May and August 1996. *Macrocystis pyrifera* was collected at San Roque (27°10'37"N, 114°26'11"W) and *Eisenia arborea, Gelidium robustum* (Gardner) Hollenberg & Abbott, and *Phyllospadix torreyi* were collected at Punta Prieta (27°00'32"N, 114°02'44"W). *M. pyrifera* samples were collected from the surface canopy of kelp beds by cutting 10 fronds at 1-m depth. At Punta Prieta, samples of about 5 kg fresh weight each of *G. robustum* and *P. torreyi*, and 10 individuals of *E. arborea* were collected by a SCUBA diver at 3-m depth. Samples were selected at random within populations. Plants were transported on ice to the laboratory, washed with fresh water to remove sea salt and animals, and dried at 50°C. Samples were ground in a laboratory mill to 0.5 mm and stored at room temperature.

Moisture (unbound water content), crude protein, crude fibre, ether extractables, and ash were analysed using methods of the Association of Official Agricultural Chemists (1995) in three dry, pooled samples. Moisture was determined by heating a sample in a furnace at 70°C until weight stabilized. Total nitrogen was determined by the micro-Kjeldahl technique and protein was estimated using the factor %N X 6.25. Ash was obtained by heating the sample at 550°C for 24 hours. Crude fibre was determined by the successive hydrolysis method of extraction in acid and alkali. Ether extractables (lipid content) were determined by extraction in a Soxhlet apparatus using petroleum ether as solvent. Nitrogen-free extract (carbohydrate fraction) was obtained as the difference between measured constituents and total percentage dry weights: (100% - % protein - %ash - %crude fibre - %lipids).

To test whether measured variables differed significantly among species, one-way ANOVA (Sokal and Rohlf, 1995) was performed for each variable. For each species, quarterly values for a variable were considered as replicates for ANOVA. As sampling dates were separated by intervals of about 3 months, ANOVAs were performed through randomisation tests, because they do not assume random sampling (Edgington, 1987). After ANOVAs, independent t-tests, through randomisation tests, were performed to determine if differences between species were significant. The validity of using several t-tests after ANOVA follows the work of Soto and Hurlbert (1991). Randomisation tests were performed with 1000 random permutations, using the Randomisation Tests program for DOS written by Edgington (1987).

RESULTS

All species had high water content. *G. robustum* had the lowest average moisture (65±6%, sd) and was significantly different from the rest of the species, followed by *Eisenia arborea* (75±4%, sd), *Phyllospadix torreyi* (80±5%, sd), and *M. pyrifera* (83±6%, sd).

Macroconstituents (nitrogen-free extract, protein, and ash) comprised nearly 90% dry weight of algae and nearly 80% of sea grass. Chemical composition of the four species varied within the species during the year (Table 1) and from one species to another (Fig. 1). *M. pyrifera* had the lowest protein content (8.4%); *G. robustum* had the highest (20.9%) (Table 1). The average protein content was highest in red algae *G. robustum*, and was significantly different from other species. Differences in crude protein were not detected for brown algae and sea grass (Fig. 1). Ash varied from 6.9% in *P. torreyi* to 37.5% in *M. pyrifera* (Table 1). The average of samples during the year showed that *M. pyrifera* ash was different than *E. arborea* and *G. robustum* (Fig. 1). Crude fibre varied from 4.3% in *G. robustum* to 17.6% in *P. torreyi* (Table 1). Ether extractables were low in the four species, ranging from 0.3% to 1.1% (Table 1). Differences in annual averages between species were not detected. Nitrogen-free extract varied from 46% in *M. pyrifera* and *P. torreyi* to 68% in (Table 1).

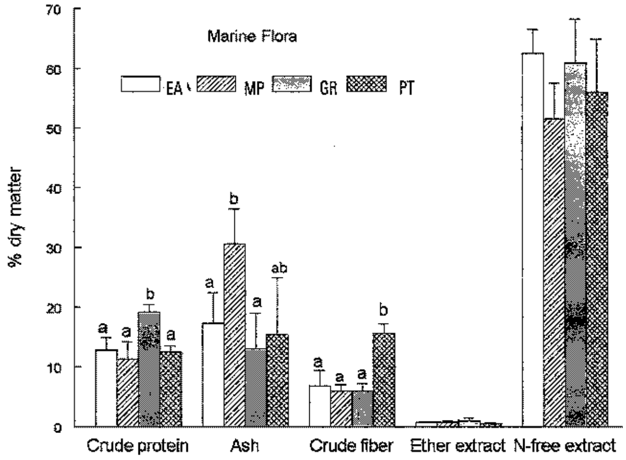

Figure 1. Chemical composition by species. EA = *Eisenia arborea*, MP = *Macrocystis pyrifera*, GR = *Gelidium robustum*, PT = *Phyllospadix torreyi*. Means ± sd, n=4. Values with different superscript are significantly different.

Table I. Seasonal chemical composition by percent dry matter

Species	Season	CP	Ash	CF	EE	NFE
Eisenia arborea	Autumn	14.9	18.2	4.7	0.9	61.4
	Winter	10.7	24.1	5.6	0.6	59.0
	Spring	11.4	13.9	5.9	0.6	68.2
	Summer	14.2	12.8	10.7	0.6	61.7
Macrocystis pyrifera	Autumn	9.1	26.5	4.8	0.7	59.0
	Winter	14.2	33.3	5.9	1.0	45.6
	Spring	13.3	25.3	7.2	0.4	53.7
	Summer	8.4	37.5	5.8	0.8	47.6
Gelidium robustum	Autumn	20.9	19.9	7.0	0.3	51.9
	Winter	18.7	7.1	6.4	1.3	66.6
	Spring	18.1	9.4	4.3	1.1	67.1
	Summer	19.0	15.8	6.2	1.0	57.9
Phyllospadix torreyi	Autumn	11.7	28.6	13.8	0.5	45.4
	Winter	13.2	10.5	16.0	0.3	60.0
	Spring	13.5	15.7	17.6	0.5	52.6
	Summer	11.7	6.9	15.1	0.5	65.8

Each value is the average of three pooled samples.

Coefficient of variation was less than 15%.

CP = crude protein, CF = crude fibre, EE = ether extract, NFE = nitrogen-free extract.

The seasons of maximum and minimum nitrogen-free extract were different among species.

DISCUSSION

Chemical composition of the four species varied seasonally and among species. Geographic distribution, season, wave exposure and currents, nutrient concentrations, depth, temperature, and development stage of marine plants are factors that influence their chemical characteristics (Jensen and Haug, 1956). Percent protein, crude fibre, ether extractables, ash, and nitrogen-free extract for *Macrocystis pyrifera* fall within the ranges reported in the literature for Mexican populations (Manzano and Rosales, 1989; Rodríguez and Hernández, 1991; Castro *et al.*, 1994b). Differences observed among studies might be caused by geographical and seasonal variations of brown algae populations sampled. The minimum proteins were detected in summer, when sea temperature increased from 13.3°C in June to 20.6°C in September 1996 (data not shown). High temperature is generally associated with decrease in nutrients and subsequent reduced growth rate (Hernández-Carmona, 1988). Rodríguez-Montesinos and Hernández-Carmona (1991), studied samples of *M. pyrifera* from three localities on the West Coast of Baja California and reported that maximum proteins in different seasons occurred at the most southerly sampling sites. The maximum value at Ensenada, B.C. (northernmost site) occurred in winter (9.45%), and at Bahía Tortugas, B.C.S. (southernmost site), it occurred in summer (12.43%). However, contrasting results were obtained from the population analysed in this study at San Roque, B.C.S., which is close to Bahía Tortugas. Here, the season with the maximum value was the same as that reported for Ensenada (Rodríguez-Montesinos and Hernández-Carmona, 1991). This suggests that differences in protein content are related not only to latitudinal temperature differences, but also to factors associated with local environmental conditions. For the other species, there is no previous information concerning seasonal variations in chemical composition or growth stage.

Red algae had higher protein content than brown algae. This agrees with other studies for the Pacific Coast of Mexico (Manzano and Rosales, 1989; Ballesteros *et al.*, 1990 and 1991; Rodríguez and Hernández, 1991; Castro *et al.*, 1994b; Pérez, 1997). In a review of seaweed proteins, Fleurence (1999) mentioned that the protein fraction of brown seaweed was low (3 - 15% dry weight) compared with that of green or red seaweed (10 - 47% dry weight), except for the brown algae *Undaria pinnatifida* (wakame), which had protein between 11 and 24% dry weight. The protein content in leaves of the sea grass *Phyllospadix torreyi* fell within the range reported for those of other sea grasses, such as *Zostera marina* L. from Ireland, Washington and Alaska (4 - 14%), and *Thalassia testudinum* Banks ex König from Gulf of Mexico (8 - 22%). In contrast, ash and lipid constituents in *P. torreyi* were lower than in *Z. marina* (14 - 47% and 1.7 – 5.7%, respectively) and *T. testudinum* (29 - 44% and 0.9 - 4.0%, respectively) (Dawes, 1998). As with other flowering plants, the composition of different sea grasses show pronounced seasonal and interspecific variations (Dawes, 1998).

The value of food for sea fauna depends on many factors, including nutrient composition, availability, presence of chemical deterrents, palatability, and digestibility (Mercer *et al.*, 1993; Fleming, 1995). Differences in growth have been found in abalone fed with seaweed of different chemical composition. In California, species with high protein content, such as *Plocamium cartilagineum* and *Gelidium robustum*, are nonetheless of low acceptability to green abalone *Haliotis fulgens*, and support only minimal growth (Leighton, personal comment). When juvenile green abalone from Mexican coastal populations were reared in the laboratory, they grew better when fed *M. pyrifera* than species with higher protein content, such as *G. robustum* and *P. torreyi* (Serviere-Zaragoza *et al.*, 2001). Feeding experiments are necessary to evaluate adequacy of marine plants as food for Mexican abalone aquaculture. The natural feeding biology of local abalone species should be more thoroughly studied, so that traditional aquaculture feed can be supplemented with algae or elements from an artificial diet, if there is no low-cost artificial diet with appropriate ingredients.

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