Chemical composition of red, brown and green macroalgae with economical and ecological interest

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Seaweeds are a very interesting natural source of compounds that could be used in foods, pharmaceutics or cosmetics. Considering their great taxonomic diversity, research on identification of biologically active compounds is encouraging in such a vast untapped source. Some algae live in complex habitats and are often subject to extreme conditions. Their metabolism can be influenced by parameters such as water temperature, salinity, light and nutrients, being forced to quickly adapt to continuously new environmental conditions and in order to survive they produce a wide variety of biologically active secondary metabolites. The main objective of the present study was to determine the chemical composition of six different species of red algae *Osmundea pinnatifida* (Ceramiales), *Grateloupia turuturu* (Halymeniales) and *Gracilaria gracilis* (Gracilariales), brown algae *Sargassum muticum* (Fucales) and *Saccorhiza polyschides* (Tilopteridales) and of green algae *Codium tomentosum* (Bryopsidales). Proximal composition, fatty acids profile and elemental composition was determined in the six seaweeds. The chemical composition in terms of proximate and elemental composition showed significant differences among brown, red and green seaweeds as well as within the species. Protein content, total sugar and fat contents ranged between 14.4 and 23.8%, 32.4 and 49.3% and 0.6-3.6%. Highest total phenolic content was observed in *C. tomentosum* followed by *S. muticum* and *O. pinnatifida*. Fatty acid (FA) composition covered the branched chain C13ai to C22:5 n3 with variable content in n6 and n3 FA; low n6:n3 ratios were observed in *O. pinnatifida*, *G. turuturu* and *C. tomentosum*. Some species may be seen as good sources of Ca, K, Mg and Fe. Based on their chemical profile the six seaweeds are of potential economical interest in the food and nutraceutical industry.

Keywords: Seaweeds, Chemical composition, Elements, Fatty acids

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INTRODUCTION

Seaweeds are a very interesting natural source of compounds that could be used in foods, pharmaceutics or cosmetics. Considering their great taxonomic diversity, research on identification of biologically active compounds is encouraging in such a vast untapped source. Some algae live in complex habitats and are often subject to extreme conditions. Their metabolism can be influenced by parameters such as water temperature, salinity, light and nutrients, being forced to quickly adapt to continuously new environmental conditions and in order to survive they produce a wide variety of biologically active secondary metabolites.

OBJECTIVES: To determine the chemical composition of six different species of red algae *Osmundea pinnatifida* (Ceramiales), *Grateloupia turuturu* (Halymeniales) and *Gracilaria gracilis* (Gracilariales), brown algae *Sargassum muticum* (Fucales) and *Saccorhiza polyschides* (Tilopteridales) and of green algae *Codium tomentosum* (Bryopsidales).

MATERIAL & METHODS

Seaweeds

Red

Brown

Green

Collected in Buarcos Bay, Figueira da Foz, Portugal)

Washed, dried at 60 ºC and milled (<1.0 mm particle size)

1. Proximate composition
2. Fatty acids
3. Elemental composition

Moisture

Organic matter — AOAC methods (1990)

Ash

Protein: Kjeldahl method (conversion factor of 6.25)

Total sugar: By calculation, i.e. by subtracting protein content and fat content from total organic content.

Total fat: Soxhlet extraction

Phenolic content: Folin-Ciocalteu colorimetric method using cathecol as standard.

Sample preparation: Procedures according to Sánchez-Avila et al. (2009)

Quantification purposes: Samples were added with 100 µL of methyl tricosanoate (1.28 mg/mL) prior to derivatization. FAME were analysed in a gas chromatograph HP6890A (Hewlett-Packard, Avondale, PA, USA), equipped with a flame-ionization detector (GLC-FID) and a BPX70 capillary column (50m x 0.32 mm x 0.25 µm; SGE Europe Ltd, Courtaboeuf, France) according to the conditions described by Vingering & Ledoux (2009).

Identification of fatty acids: Supelco 37 and CRM-164 were used. GLC-Nestlé36 was assayed for calculation of response factors and detection and quantification limits (LOD: 0.15 µg/mL; LOQ: 0.46 µg/mL).

Microwave-assisted acid digestion: Microwave-assisted digestion proposed by Speedwave MW-3+ (Berghof, Germany) for dried plant samples with some modifications was used. Samples with up to 0.2 g dry seaweed were placed in the digestion vessel and added with 5 mL of concentrated nitric acid.

Determination of 15 elements: The elemental composition was determined using an inductively coupled plasma (ICP) optical emission spectrometer model Optima™ 7000 DV ICP-OES (Dual View, PerkinElmer Life and Analytical Sciences, Shelton, CT, USA) with radial plasma configuration.

RESULTS & DISCUSSION

Table 1: Proximate composition of seaweeds

Parameter	*G. gracilis*	*O. pinnatifida*	*G. turuturu*	*S. muticum*	*S. polyschides*	*C. tomentosum*
% Moisture ($g/100g_{dry\ seaweed}$)	7.99±0.02 a	11.77±0.01 e	11.68±0.05 e	9.54±0.08 c	10.88±0.04 d	9.0±0.2 b
% Total Protein ($g/100g_{dry\ seaweed}$)	20.2±0.6 d	23.8±0.6 f	22.5±0.3 e	16.9±0.2 b	14.44±0.1 a	18.8±0.1 c
% Total sugars[1] ($g/100g_{dry\ seaweed}$)	46.6	32.4	43.2	49.3	45.6	32.8
% Total Fat ($g/100g_{dry\ seaweed}$)	0.60±0.01 a	0.9±0.1 a	2.2±0.1 c	1.45±0.07 b	1.1±0.1 ab	3.6±0.2 d
Total phenolic content ($mg\ carbocol\ eqA/g_{dry\ seaweed}$)	226±14 a	337±22 b	208±8 a	499±32 c	224±13 a	920±64 d
% Organic matter ($g/100g_{dry\ seaweed}$)	67.21±0.01 d	57.5±0.2 a	67.80±0.06 d	67.41±0.02 d	60.97±0.05 c	55.0±0.7 b
% Ash ($g/100g_{dry\ seaweed}$)	24.8±0.03 b	30.62±0.25 a	20.52±0.01 c	22.94±0.06 d	28.15±0.01 e	35.99±0.48 f

[1]% Total Sugars (%) = Organic matter (%) – Total Protein (%) - Total Fat (%); a-f, in a raw: Different letters indicate significant differences ($p<0.05$) between species

The chemical composition in terms of proximate and elemental composition showed significant differences among brown, red and green seaweeds as well within the species.

Protein content, total sugar and fat contents ranged between 14.4 and 23.8%, 32.4 and 49.3% and 0.6-3.6%.

Highest total phenolic content was observed in *C. tomentosum* followed by *S. muticum* and *O. pinnatifida*.

Table 2: Fatty acid composition (g FA/$100g_{fat}$) and total FAT content (µg FA/$mg_{dry\ seaweed}$) of the seaweeds

	G. gracilis		*O. pinnatifida*		*G. turuturu*		*S. muticum*		*S. polyschides*		*C. tomentosum*	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
C13ai	0.30 c	0.09	0.48 c	0.06	0.37 c	0.07	1.25 a	0.09	0.71 b	0.03	0.40 c	0.07
C14	5.37 b	0.01	6.46 a	0.01	2.80 d	0.02	2.94 d	0.01	3.85 c	0.03	1.01 e	0.32
C14:1 c9	0.87 a	0.01	0.08 c	0.01	0.87 c	0.01	0.23 b	0.01	0.07 c	<0.01	0.23 b	0.02
C15	0.51 a	0.01	0.56 a	0.01	0.51 a	0.03	0.31 b	0.01	0.36 b	0.05	0.14 c	0.02
C16	52.54 a	0.03	48.03 b	0.02	35.86 c	0.08	30.33 C	0.03	25.49 d	0.04	31.33 c	0.01
C16:1 c7 n9	0.06 d	<0.01	0.13 c	0.02	0.26 b	0.00	0.12 c	0.01	0.70 a	0.03	0.70 a	0.03
C16 Phy	1.23 c	0.06	0.33 d	0.01	1.29 c	0.03	1.16 c	0.13	3.15 a	0.08	1.62 c	0.06
C16:1 c9	0.29 e	0.07	1.25 c	0.01	0.96 d	0.02	6.08 a	0.13	2.17 b	0.09	1.25 c	0.06
C16:2 c9 t12	<LOD e	—	<LOD e	—	0.84 d	<0.01	0.09 c	0.01	0.22 b	0.01	1.06 a	0.14
C17	0.27 a	0.01	0.12 B c	0.01	0.11 c	<0.01	0.09 c	0.02	0.14 b	0.04	0.10 c	0.01
C16:2 c9 c12	<LOD e	—	0.39 b	<0.01	0.08 c	<0.01	0.87 a	0.02	0.13 c	0.03	<LOD d	—
C17:1 c10	0.13 b	0.01	0.14 b	0.01	0.10 b	<0.01	0.15 ab	0.01	0.17 a	<0.01	0.16 ab	0.02
C16:3 c7 c10 c13	<LOD d	—	<LOD d	—	<LOD d	—	0.22 b	0.02	0.03 c	<0.01	10.77 a	0.01
C18	1.56 a	0.03	0.94 b	0.04	1.10 b	0.02	0.47 c	0.01	0.78 d	0.01	0.62 d	0.01
C18:1 c9 n9	11.13 b	0.39	12.51 a	0.00	6.54 d	0.01	8.59 c	0.02	11.68 b	0.78	12.57 a	0.01
C18:1 c11	1.41 c	0.02	3.90 a	0.02	2.12 b	0.17	0.48 c	0.02	2.32 b	0.07	1.01 d	0.01
C18:2 c9 c12 n6	0.85 d	0.05	1.43 b	0.01	1.79 c	0.05	5.73 a	0.01	5.08 b	0.46	5.12 b	0.01
C18:3 t9 t12 c15 n3	0.22 d	0.03	0.32 c	0.03	0.79 a	0.02	0.51 b	0.02	0.03 e	<0.01	0.06 e	<0.01
C18:3 c6 c9 c12 n6	0.34 d	0.01	0.31 d	0.02	0.87 c	<0.01	5.87 a	0.01	0.65 c	0.03	2.84 b	0.14
C18:3 c9 c12 c15 n3	0.11 b	0.02	<LOD d	—	0.10 b	<0.01	0.34 c	0.01	6.47 b	0.07	17.38 a	0.02
C20	0.11 d	0.01	0.16 c	0.01	0.07 e	<0.01	5.18 a	0.01	0.59 b	<0.01	0.16 c	0.01
C20:1 c9	0.22 d	0.02	0.08 d	<0.01	0.09 d	<0.01	2.09 b	0.01	11.09 a	0.23	1.97 b	0.01
C20:1 c11	0.46 c	0.03	0.55 b	0.02	1.03 a	0.01	0.58 b	0.05	0.07 d	0.01	<LOD e	—
C20:3 c11 c14 c17	0.35 c	0.05	<LOD d	—	0.47 a	0.13	<LOD d	—	0.53 a	0.01	0.51 a	0.03
C20:4 AA n6	16.82 a	0.50	4.92 d	0.01	12.28 a	0.05	12.43 c	0.04	15.01 b	0.03	2.86 e	0.01
C22	<LOD b	—	<LOD b	—	<LOD b	—	<LOD b	—	<LOD b	—	1.73 a	0.01
C22:1 c9	<LOD e	—	<LOD e	—	0.23 c	0.02	2.30 a	0.04	0.54 b	0.01	0.25 c	0.00
C20:5 n3	<LOD f	—	15.58 b	0.14	29.92 a	0.02	7.54 c	0.02	5.77 d	0.02	1.67 e	0.02
C22 c13 c16	<LOD b	—	<LOD b	—	0.22 a	0.01	<LOD b	—	<LOD b	—	<LOD b	—
C24	0.17 b	0.01	<LOD e	—	0.05 d	0.01	0.20 b	0.02	0.11 c	0.01	0.93 a	0.02
C22:5 n6	<LOD c	—	<LOD c	—	<LOD c	—	0.18 b	0.01	0.31 a	0.01	<LOD c	—
C24:1	0.44 a	<0.01	0.13 c	0.03	0.18 b	0.02	<LOD d	—	0.16 bc	0.04	<LOD d	—
C22:5 n3	0.61 a	0.09	<LOD c	—	0.08 b	<0.01	<LOD c	—	<LOD c	—	<LOD c	—
SFA	63.34 a	0.24	58.07 a	0.03	42.74 b	0.19	42.17 b	0.19	36.42 c	0.16	36.88 bc	0.02
MUFA	15.24 d	0.34	18.92 c	0.13	11.64 e	0.03	21.13 b	0.18	29.09 a	0.08	18.51 c	0.08
PUFA	21.22 c	0.58	23.01 c	0.03	45.72 a	0.16	36.70 b	0.01	34.49 b	0.07	42.60 a	0.10
Total n9	11.78 b	0.33	13.10 a	0.11	7.61 d	0.01	9.35 c	0.03	12.20 b	0.89	12.77 ab	1.36
Total n6	20.14 b	0.16	6.68 e	0.02	14.41 c	0.06	27.46 a	0.30	21.48 b	0.13	10.99 d	0.19
Total n3	1.38 e	0.44	16.08 b	0.13	31.56 a	0.11	8.88 d	0.17	13.21 c	0.03	31.57 a	0.72
n6/n3	15.36 a	1.83	0.42 de	0.01	0.46 d	0.05	3.09 b	0.44	1.63 c	0.14	0.35 e	0.02
µg FA/$mg_{dry\ seaweed}$	12.31 d	0.09	16.47 c	0.31	20.89 b	0.59	17.30 c	0.44	19.96 b	0.14	27.58 a	0.15

The fatty acid (FA) composition covered the branched chain C13ai to C22:5 n3 with variable content in n6 and n3 FA; low n6:n3 ratios were observed in *O. pinnatifida*, *G. turuturu* and *C. tomentosum*.

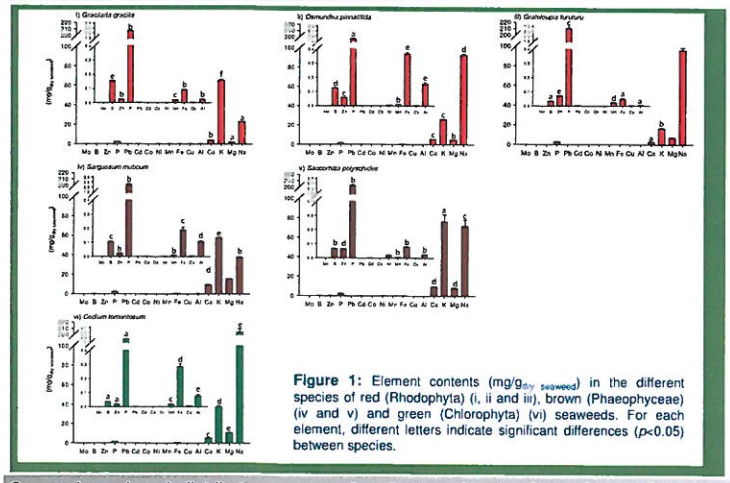

Figure 1: Element contents ($mg/g_{dry\ seaweed}$) in the different species of red (Rhodophyta) (i, ii and iii), brown (Phaeophyceae) (iv and v) and green (Chlorophyta) (vi) seaweeds. For each element, different letters indicate significant differences ($p<0.05$) between species.

Concerning mineral distribution per species, inter and intra algae class variations were observed. Some species may be seen as good sources of Ca, K, Mg and Fe. For example, K was the most predominant element found in *S. muticum*, *G. gracilis* and *S. polyschides* with contents ranging between 16.28 to 76.54 $mg/g_{dry\ seaweed}$.

Conclusions

Based on their chemical profile the six seaweeds are of potential economical interest in the food and nutraceutical industry.

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