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Analysis of some chemical nutrients in four Brazilian tropical seaweeds

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ABSTRACT. Seaweeds have various chemical components with beneficial effects for human use; however, their nutritional values in Brazilian species are not well known. This study aimed to evaluate the content of water, ash, protein, carbohydrate, and lipid in four seaweeds (*Hypnea musciformis*, *Solieria filiformis*, *Caulerpa cupressoides* and *C. mexicana*). Algal constituents were determined by difference, gravimetric or colorimetric method, being the values expressed as g 100 g^{-1} dehydrated weight (d.w.). Results revealed that the water (10.7 ± 0.18-15.06 ± 1.14 g 100 g^{-1} d.w.), ash (7.79 ± 0.87-15.12 ± 0.51 g 100 g^{-1} d.w), protein (17.12 ± 0.99-20.79 ± 0.58 g 100 g^{-1} d.w.), lipid (0.33 ± 0.01-3.77 ± 0.13 g 100 g^{-1} d.w.) and carbohydrate (38.07 ± 0.32-54.24 ± 0.157 g 100 g^{-1} d.w.) contents varied between the species ($p < 0.05$). *H. musciformis* and *S. filiformis* (Rhodophyta) had highest ash contents (14.14 ± 1.23-15.12 ± 0.51 g 100 g^{-1} d.w.), whereas lipids were higher for *Caulerpa* species (Chlorophyta) (1.52 ± 0.17-3.77 ± 0.13 g 100 g^{-1} d.w.) ($p < 0.05$). Protein and carbohydrate were the most sources in all the species. Therefore, the studied seaweeds could be a potential source of food ingredients for diets.

Keywords: marine macroalgae, chemical components, proximate determination.

Análise de alguns nutrientes químicos em quatro algas marinhas tropicais brasileiras

RESUMO. As algas marinhas possuem vários componentes químicos com efeitos benéficos para uso humano. Entretanto, não são conhecidos bem seus valores nutricionais em espécies brasileiras. Objetivou-se avaliar os conteúdos de água, cinza, proteína, carboidrato e lipídio em quatro algas marinhas (*Hypnea musciformis*, *Solieria filiformis*, *Caulerpa cupressoides* e *C. mexicana*). Os constituintes das algas foram determinados por método de diferença, gravimétrico ou colorimétrico, sendo os valores expressos em g 100 g^{-1} de peso desidratado (p.d.). Os resultados revelaram que os conteúdos de água (10,7 ± 0,18-15,06 ± 1,14 g 100 g^{-1} p.d.), cinza (7,79 ± 0,87-15,12 ± 0,51 g 100 g^{-1} p.d.), proteína (17,12 ± 0,99-20,79 ± 0,58 g 100 g^{-1} p.d.), lipídio (0,33 ± 0,01-3,77 ± 0,13 g 100 g^{-1} p.d.) e carboidrato (38,07 ± 0,32-54,24 ± 0,157 g 100 g^{-1} p.d.) variaram entre as espécies ($p < 0{,}05$). *H. musciformis* e *S. filiformis* (Rhodophyta) tiveram os maiores conteúdos de cinza (14,14 ± 1,23-15,12 ± 0,51 g 100 g^{-1} p.d.), enquanto as espécies *Caulerpa* (Chlorophyta) foram para lipídio (1,52 ± 0,17-3,77 ± 0,13 g 100 g^{-1} p.d.) ($p < 0{,}05$). Todas as espécies foram fontes maiores em proteína e carboidrato. Portanto, as algas marinhas estudadas poderiam ser uma fonte de ingrediente alimentar potencial para dietas.

Palavras-chave: macroalgas marinhas, componentes químicos, determinação proximal.

Introduction

In recent years, serious problems concerning the global food security have reflected in the maintenance and improvement of quality of life of people, especially those living in poor regions of the world. The growing human population, global climatic changes and the diversification of terrestrial food sources for other needs have also negatively contributed to unavailability of foods with nutritional quality for human consumption (ROSEGRANT; CLINE, 2003).

Algae comprise a heterogeneous group of organisms abundantly occurring in several ecosystems, mainly in the oceans (GUERRY et al., 2009), and are divided into three different phyla (Chlorophyta, Rhodophyta and Phaeophyta) (JOLY, 1965). These organisms have been consumed as seafoods since at least 600 BC, and mainly in Oriental countries and more recently, in USA and Europe (DAWCZYNSKI et al., 2007). They play important biological, environmental, and ecological roles in coastal ecosystems (CHOPIN; SAWHNEY, 2009; YANG et al., 2006), and have interesting functional properties in the food, cosmetic and pharmaceutical industries (CAMPO et al., 2009; SILVA et al., 2010; SMIT, 2004). Their main chemical components include ash, mineral, dietary protein, lipid and carbohydrate (mainly agar, carrageenan and alginate) (CAMPO et al., 2009; MABEAU; FLEURENCE, 1993; MURANO et al., 1997; WONG; CHEUNG, 2000), thus representing sources of novel ingredients for human and animal diets (MOHAMED et al., 2012; URBANO; GOÑI, 2002; VALENTE et al., 2006).

The biotechnological importance of natural products (e.g., phenolic compounds, sulfated polysaccharides, lectins, carotenoids and organic acids) (CORDEIRO et al., 2006; MAEDA et al., 2005; MABEAU; FLEURENCE, 1993; POMIN; MOURÃO, 2008) extracted from seaweeds could motivate the industries to development of novel ingredients for commercial use not only due to their rheological aspects (e.g. gelling, thickening and stabilizers agents) (CAMPO et al., 2009; SMIT, 2004; WONG; CHEUNG, 2000), but also the medicinal properties (e.g., anticancer, antiallergy, antidiabetes, antioxidant, anti-inflammatory, antithrombosis, antiobesity, antilipidemia and antihypertensive) (CORDEIRO et al., 2006; DE ARAÚJO et al., 2012; GUPTA; ABU-GHANNAM, 2011; MAEDA et al., 2005; MOHAMED et al., 2012; QUINDERÉ et al., 2013 and 2014; SMIT, 2004; WIJESEKARA et al., 2011) of the different classes of compounds found.

The nutritional value of seaweeds has been scarcely studied; however, some reports have shown that they present low lipid content but are rich in proteins and carbohydrates. For example, Mabeau and Fleurence (1993) reported that edible seaweeds have 33-50% total fibers (cell-wall sulfated polysaccharides that are not entirely degraded by human gastrointestinal tract enzymes), whereas the protein contents of brown seaweeds are low (5-15% dry weight) in comparison with those found in green and red seaweeds (10-30% dry weight). Lipids would represent 1-3% of algal dry weight. De Oliveira et al. (2009) showed that the contents of ash (13-25% dry weight), lipid (below 1% dry weight) and protein (10-14.8% dry weight) found in twenty-nine Brazilian seaweeds species could vary during the year. Also, Gressler et al. (2010), evaluating the proximate composition in four different species of marine benthic algae (*Laurencia filiformis*, *L. intricate*, *Gracilaria domingensis* and *G. birdie*; Rhodophyta) collected in Brazil, obtained contents (% dry weight) of 1.1-6.2% total lipids, 4.6-18.3% proteins and 22.5-38.4% ash, respectively. The proximate composition found in *Caulerpa* species (Chlorophyta) by Kumar et al. (2011) was reasonable in terms of nutrients. Recently, the marine algae *Ulva lactuca* (Chlorophyta) and *Gracilaria salicornia* (Rhodophyta) were also described as a potential food source by Tabarsa et al. (2012).

In Brazil, some studies concerning the occurrence of species showed seasonal variation during the year, which is reflected in their biochemical constituents (MARINHO-SORIANO et al., 2006; DE OLIVEIRA et al., 2009). The seaweeds *Hypnea musciformis* (Wulfen) J. V. Lamouroux, *Solieria filiformis* Kützing P. W. Gabrielson (Rhodophyta), *Caulerpa cupressoides* var. *lycopodium* C. Agardh and *C. mexicana* Sonder ex Kützing (Chlorophyta) are widely registered along of the Brazilian coast (JOLY, 1965). Previous studies demonstrated that the species *H. musciformis*, *S. filiformis* and *C. cupressoides* var. *lycopodium* have natural products (lectins and sulfated polysaccharides) with potential pharmacological value (ABREU et al., 2012; CORDEIRO et al., 2006; DE ARAÚJO et al., 2011, 2012; HOLANDA et al., 2005; RODRIGUES et al., 2010, 2011a, 2011b, 2012a, 2013a; VANDERLEI et al., 2010). Considering the demand for seaweeds as food in recent years, and once no report on nutritional assessment of these algal species has been done, it was analyzed some nutritional aspects (water, ash, protein, lipid and carbohydrate) to estimate the potential use as food supplements.

Material and methods

Marine algae

The algae *C. cupressoides* var. *lycopodium* and *C. mexicana* (Chlorophyta, Bryopsidales) were collected manually from growing natural habitat (intertidal zone) located on the Pacheco Beach (Caucaia, Ceará State, Brazil), and the algae *H. musciformis* and *S. filiformis* (Rhodophyta, Gigartinales) were obtained from the experimental cultivation at the Flecheiras Beach (03°13'06"S, 039°16'47"W) (Trairí, Ceará State, Brazil) (August, 2011). Seaweed samples were placed in plastic bags and taken to the Carbohydrates and Lectins Laboratory (CarboLec), Department of Biochemistry and Molecular Biology, Federal University of Ceará (UFC), Brazil. The nutritional analyses were performed at Federal Institute of Ceará, Limoeiro do Norte, Brazil. The algae were cleaned of epiphytes, washed with distilled water and stored (-20°C) until use. Voucher specimens of the algae were classified and archived by Ana Cecília Fortes Xavier at the Prisco Bezerra Herbarium (UFC).

Sample preparation

The algae were dehydrated and then stored in plastic recipients (25°C) in the dark. All experimental determinations were performed in triplicates from specimens collected.

Water determination

This assay was based on Kumar et al. (2011). Briefly, the fresh algal matter was oven dried at 60°C to constant weight and then subtracting the dehydrated algal weight value from the wet weight.

Ash determination

The determination of the ash content was performed based on De Oliveira et al. (2009) gravimetrically after heating at 550°C for 18h in a muffle furnace.

Protein determination

This analysis was carried out according to De Oliveira et al. (2009) and Kumar et al. (2011). To determine the protein content, we previously examined the nitrogen content using an Elemental Analyzer. From this, the percentage proteins were calculated by multiplying the nitrogen content by a factor of 6.25.

Lipid determination

The content of lipids was estimated using a modified method according to Gressler et al. (2010). This was based on a 14 mL of a mixture of chloroform and methanol (2:1) followed by the addition of 2 g dehydrated algae (oven drying, 60°C) into a tube. Then, the tube was closed, mixed in a vortex mixer for 2 min. and the extract was filtered through paper. The residue was re-extracted with 5 mL with the same solvent mixture in a vortex mixer (30 s). After that, the resulting extract was filtered through paper and the two filtrates were pooled and concentrated to dryness under $N_{2(g)}$. Lipids were gravimetrically determined on triplicate aliquots of each liquid extract.

Carbohydrate determination

The analysis of the carbohydrate content (including dietary fiber) was performed by difference of the chemical components (De Oliveira et al., 2009).

Statistical analysis

The data were presented as mean ± standard deviation (SD) for the chemical components. Analysis of variance (ANOVA) was run for unpaired values. Values of $p < 0.05$ were considered statistically significant.

Results and discussion

In this study, some proximate biochemical constituents (water, ash, protein, lipid and carbohydrate) were determined in four different species of Brazilian tropical seaweeds (*C. cupressoides* and *C. mexicana* (Chlorophyta); *H. musciformis* and *S. filiformis* (Rhodophyta)). It was observed that the nutritional components varied among the studied marine benthic macroalgae ($p < 0.05$).

Water content

Table 1 lists the water content of the seaweeds. The values ranged from 10.7 ± 0.18 g 100 g^{-1} dehydrated weight (d.w.) in *C. mexicana* (Chlorophyta) to 15.06 ± 1.14 g 100 g^{-1} d.w. in *S. filiformis* (Rhodophyta).

Table 1. Water content (g 100 g^{-1} d.w.) of four Brazilian tropical seaweeds (mean ± SD, n = 3).

Species	Water (%)
Chlorophyta	
Caulerpa cupressoides	12.21 ± 0.09 ^{c}
Caulerpa mexicana	10.7 ± 0.18 ^{ac}
Rhodophyta	
Hypnea musciformis	14.17 ± 1.28 ^{b}
Solieria filiformis	15.06 ± 1.14 ^{b}

Different superscript letters indicate values that differ statistically ($p < 0.05$, ANOVA).

Interestingly, red seaweed samples contained higher values of water content compared with green algae ($p < 0.05$). Possibly, Rhodophyta species are able to accumulate water, thus suggesting a new insight in terms of response of these marine organisms to marine habitat (ANDRADE et al., 2005; RODRIGUES et al., 2012b).

Ash content

All seaweed samples exhibited high ash contents (from 11.28 ± 0.33 to 15.12 ± 0.51 g 100 g^{-1} d.w.), except *C. mexicana* (Chlorophyta) that presented 7.79 ± 0.87 g 100 g^{-1} d.w. ($p < 0.05$) (Table 2) similar to terrestrial plants (5-10%), based on De Oliveira et al. (2009) and Tabarsa et al. (2012), and in the red seaweed *Porphyra* spp. (9.3 ± 0.2% dry weight) (MARSHAM et al., 2007).

Table 2. Ash content (g 100 g^{-1} d.w.) of four Brazilian tropical seaweeds (mean ± SD, n = 3).

Species	Ash (%)
Chlorophyta	
Caulerpa cupressoides	11.28 ± 0.33 ^{c}
Caulerpa mexicana	7.79 ± 0.87 ^{a}
Rhodophyta	
Hypnea musciformis	14.14 ± 1.23 ^{b}
Solieria filiformis	15.12 ± 0.51 ^{b}

Different superscript letters indicate values that differ statistically ($p < 0.01$, ANOVA).

The presence of ash could be strongly attributed to ester sulfate groups and uronic acids of the polysaccharides (CHARLES et al., 2007; DE ARAÚJO et al., 2011; RODRIGUES et al., 2013a) and to mineral elements (MOHAMED et al., 2012) and metals also associated with carbohydrates (ANDRADE et al., 2005; CAMPO et al., 2009).

Recent studies demonstrated that the seaweeds *C. cupressoides* (Chlorophyta) and *S. filiformis* (Rhodophyta) are rich sources of sulfated polysaccharides (DE ARAÚJO et al., 2011; RODRIGUES et al., 2011a), a diverse class of highly complex and heterogeneous anionic polymers found at high concentration in the extracellular matrix of these organisms (MURANO et al., 1997; POMIN; MOURÃO, 2008). Rupérez et al. (2002) suggested that the mineral content and trace elements for human diet can be found in seaweeds.

Tabarsa et al. (2012) found ash as the most component in *Gracilaria salicornia* (Rhodophyta) and *U. lactuca* (Chlorophyta), with values of 38.91% and 18.03 g 100 g^{-1} dry weight, respectively. Similar results (from 21.3 to 22.6% dry weight) were found in *Hypnea japonica*, *H. charoides* (Rhodophyta) and *U. lactuca* (Chlorophyta), respectively (WONG; CHEUNG, 2000). Gressler et al. (2012) obtained ash contents ranging from 22.5 ± 0.3 to 38.4 ± 0.1% dry weight for *G. domingensis*, *G. birdiae* (Rhodophyta), *L. filiformis* and *L. intricata* (Phaeophyta), respectively.

In our case, the ash content found in Chlorophyta species was about 1.95-fold lower than those found in Rhodophyta species. The red seaweed *Corallina officinalis* (77.8 ± 0.2% dry weight) presented ash content 5.2-fold higher in comparison with the red seaweed *S. filiformis* (Table 2) (MARSHAM et al., 2007). Kumar et al. (2011) found highest ash values in *C. scalpelliformis* (40.77 ± 2.15% dry weight), *C. veravelensis* (33.7 ± 2.73% dry weight) and *C. racemosa* (24.2 ± 2.2% dry weight), respectively. Similar results of ash contents for seven *Caulerpa* species were also reported by Dawes and Goddard (1978). These conflicting data may be the result of the use of different species, season of the year and/or environmental growth conditions (GRESSLER et al., 2010).

Protein content

In respect to the protein content of the seaweed samples, the values found varied between the species (Table 3). The protein levels ranged from 17.12 ± 0.99 to 20.79 ± 0.58 g 100 g^{-1} d.w. ($p < 0.05$), and were in accordance with those recorded for green and red seaweeds (10-47% of the dry weight) (DE OLIVEIRA et al., 2009; MABEAU; FLEURENCE, 1993; MOHAMED et al., 2012; WONG; CHEUNG, 2000). On the other hand, Marsham et al. (2007) and Yaich et al. (2011) detected 6.9 and 8.5% dry weight protein contents in *Corallina officinalis* (Rhodophyta) and *U. lactuca* (Chlorophyta), respectively.

Table 3. Protein content (g 100 g^{-1} d.w.) of four Brazilian tropical seaweeds (mean ± SD, n = 3).

Species	Proteins (%)
Chlorophyta	
Caulerpa cupressoides	20.79 ± 0.58^a
Caulerpa mexicana	18.06 ± 0.60^b
Rhodophyta	
Hypnea musciformis	17.12 ± 0.99^b
Solieria filiformis	20.31 ± 0.91^a

Different superscript letters indicate values that differ statistically ($p < 0.01$, ANOVA).

In this study, the protein content of the tropical green seaweeds *C. cupressoides* (20.79 ± 0.58 g 100 g^{-1} d.w.) and *C. mexicana* (18.06 ± 0.60 g 100 g^{-1} d.w.) were different from those obtained in *C. lentillifera* (10.41% dry weight) (MOHAMED et al., 2012), *C. veravelensis* (7.77 ± 0.59% dry weight), *C. scalpelliformis* (10.50 ± 0.91% dry weight) and *C. racemosa* (12.88 ± 1.17% dry weight), respectively, collected in the coast of India (KUMAR et al., 2011).

These findings suggest that the protein levels in *Caulerpa* species can be variable when collected from different regions and environmental conditions (DE OLIVEIRA et al., 2009; HUNG et al., 2009). Furthermore, the levels of proteins found were not comparable to those found in high-protein plants, such as soybeans (35% of the dry mass) based on Mabeau and Fleurence (1993).

The levels of proteins present in the marine macroalgae species (Table 3) were also not correlated in terms of their morphological aspects. Rodrigues et al. (2012b) revealed that the yield of crude sulfated polysaccharides from the green seaweeds *C. cupressoides*, *C. racemosa* and *C. prolifera* was dependent on the morphology of their thallium. In fact, proteins could be removed in the extraction process of sulfated polysaccharides by proteolytic digestion (DE ARAÚJO et al., 2011, 2012; RODRIGUES et al., 2011a). It is reported that the *Caulerpa* species can biosynthesize proteoglycans (a polysaccharide-protein complex) (GHOSH et al., 2004), thus the employment of enzymatic digestion is an alternative strategy to improve not only yields, but also the quality of pharmacologically important polysaccharides (DE ARAÚJO et al., 2012; RODRIGUES et al., 2010) without toxicity (DE ARAÚJO et al., 2011; QUINDERÉ et al., 2013; RODRIGUES et al., 2012a, 2013b).

The study of algal proteins and their biochemical characterization have already been reported (HOLANDA et al., 2005; SMIT, 2004). Although the protein content between the species was significantly different (Table 3), the four seaweed proteins could perhaps contain all essential amino acids comparable to those of the Food and Agriculture Organization of the United Nations/World Health Organization (FAO/WHO) requirement (WONG; CHEUNG, 2000). Some seaweeds species contain all the essential amino acids (monomeric units that form the protein structures) at levels close to that recommended, such as arginine (*Porphyra tenera*, Rhodophyta) (MABEAU; FLEURENCE, 1993), methionine (*Sargassum vulgare*, Phaeophyta), aspartic and glutamic acids (*Ulva* spp., Chlorophyta) (MOHAMED et al., 2012).

Earlier studies showed that certain algal proteins (lectins - glycoproteins with ability to agglutinate red blood cells) also work as biotechnological tools in experimental models *in vivo* and/or *in vitro* against human pathogenic bacteria (HOLANDA et al., 2005), growth of human pathogen yeasts (CORDEIRO et al., 2006) or on the immune response (ABREU et al., 2012; VANDERLEI et al., 2010). Also, phycobiliproteins have also been isolated, which have beneficial effects against neurodegenerative diseases, cancers, and gastric ulcers (MOHAMED et al., 2012).

Our data obtained for the genera *Caulerpa*, *Hypnea* and *Solieria* regarding the content of protein are valuable, since low levels of phenols are usually found in green and red seaweeds. It is described that high phenolic content in green and red seaweeds might limit protein availability *in vivo*. Further investigations on the digestibility *in vivo* of these algal proteins could provide data on the degradation process by human and animal gastrointestinal tract enzymes (CHARLES et al., 2007; MABEAU; FLEURENCE, 1993; URBANO; GOÑI, 2002).

Carbohydrate content

The content of carbohydrate in the four species analyzed is shown in Table 4. All seaweeds presented large amounts of these nutrients (38.07 ± 0.32-54.24 ± 0.157 g 100 g^{-1} d.w.) ($p < 0.05$). The Rhodophyta species (*H. musciformis* and *S. filiformis*) notably showed highest carbohydrate contents (54.24 ± 0.57 and 49.17 ± 0.38 g 100 g^{-1} d.w., respectively) than those found in *C. cupressoides* and *C. mexicana* (Chlorophyta) (47.44 ± 0.12 and 38.07 ± 0.32 g 100 g^{-1} d.w., respectively).

In general, high amounts of carbohydrate are obtained in Rhodophyta species (DE OLIVEIRA et al., 2009) compared with Chlorophyta ones (KUMAR et al., 2011). The literature describes that those present in red seaweeds play a relevant role in terms of ionic, mechanical and osmotic functions of these organisms (KLOAREG; QUATRANO, 1988), and it could explain the data listed in Table 1.

Table 4. Carbohydrate content (g 100 g^{-1} d.w.) of four Brazilian tropical seaweeds (mean ± SD, n = 3).

Species	Carbohydrates (%)
Chlorophyta	
Caulerpa cupressoides	47.44 ± 0.12^{c}
Caulerpa mexicana	38.07 ± 0.32^{b}
Rhodophyta	
Hypnea musciformis	54.24 ± 0.57^{d}
Solieria filiformis	49.17 ± 0.38^{a}

Different superscript letters indicate values that differ statistically ($p < 0.01$, ANOVA).

Accordingly, studies revealed that *S. filiformis* (Rhodophyta) exhibited yield of crude extracts containing sulfated polysaccharides varying from 14.14 to 32.64% (DE ARAÚJO et al., 2011, 2012; MURANO et al., 1997; RODRIGUES et al., 2010), and in *C. cupressoides* (Chlorophyta) ranging from 2 to 3% (RODRIGUES et al., 2011a, 2012b). The content of carbohydrate found in *Caulerpa* species (Table 4) was also consistent with Kumar et al. (2011) who reported values of carbohydrate ranging from 37.23 ± 3.05 to 48.95 ± 2.06% dry weight for *C. veravelensis*, *C. scalpelliformis* and *C. racemosa*, respectively.

Seaweeds are a rich source of polysaccharides, especially cell-wall sulfated polysaccharides that are of great interest for the hydrocolloid industries (DE ARAÚJO et al., 2012; CAMPO et al., 2009; SILVA et al., 2010; SMIT, 2004). These anionic polymers include agars (POMIN; MOURÃO, 2008), carrageenans (CAMPO et al., 2009; HUNG et al., 2009; MURANO et al., 1997), ulvans (TOSKAS et al., 2011) and fucoidans (POMIN; MOURÃO, 2008; ANDRADE et al., 2005). They are used as texturizing ingredients in many processed products (e.g., frozen desserts, chocolate milks, cottage cheese, and whipped cream) for human consumption due to their intrinsic properties (e.g., gelling and stabilizing agents). Moreover, non-dairy food products (e.g., instant products and pet foods) based on polysaccharides have been launched reported in the phycocolloid market (CAMPO et al., 2009). Pharmacological importance of sulfated polysaccharides from seaweeds is also described (CHARLES et al., 2007; DE ARAÚJO et al., 2011, 2012; POMIN; MOURÃO, 2008; RODRIGUES et al., 2010, 2011a and b, 2012a; WIJESEKARA et al., 2011; ZHANG et al., 2003), as well as the use of these sea “vegetables” as a potential source of food ingredients for animals (URBANO; GOÑI, 2002; VALENTE et al., 2006).

Although containing high amounts of carbohydrates (Table 4), these macromolecules present in seaweeds are not digested by human gastrointestinal enzymes; they are like dietary fibers (representing 33-50%, higher than levels found in most land plants) that have been associated with different important physiological effects (e.g., hypocholesterolemic and hypoglycemic) (MABEAU; FLEURENCE, 1993; PENGZHAN et al., 2003). However, the chemical nature of dietary fibers is partially known and it has not yet received much attention in terms of degradation processes by the human microflora (MABEAU; FLEURENCE, 1993) and systemic effects (CAMPO et al., 2009; DE ARAÚJO et al., 2011; GRAÇA et al., 2011).

Lipid content

Measurable differences in terms of lipids were evidenced between the phyla, as seen in Table 5. The lipid levels were higher in Chlorophyta ($p < 0.05$), but different between the *Caulerpa* species (3.77 ± 1.93 and 1.52 ± 0.17 g 100 g^{-1} d.w., respectively). Lower amounts of lipids ($p > 0.05$) in *H. musciformis* and *S. filiformis* (Rhodophyta) were also observed in this study, and reflected a different ability of accumulating lipids (GRESSLER et al., 2010).

Table 5. Lipid content (g 100 g^{-1} d.w.) of four Brazilian tropical seaweeds (mean ± SD, n = 3).

Species	Lipids (%)
Chlorophyta	
Caulerpa cupressoides	3.77 ± 0.13^a
Caulerpa mexicana	1.52 ± 0.17^b
Rhodophyta	
Hypnea musciformis	0.33 ± 0.01^c
Solieria filiformis	0.34 ± 0.02^c

Different superscript letters indicate values that differ statistically ($p < 0.01$, ANOVA).

The data showed a similarity in the lipid contents between other studied *Caulerpa* species (from 2.80 ± 0.19 to 3.06 ± 0.39% dry weight) (KUMAR et al., 2011; MOHAMED et al., 2012) and in the seaweeds *H. charoides*, *H. japonica* (Rhodophyta) and *U. lactuca* (Chlorophyta) (from 1.42 to 1.64% dry weight, respectively) (WONG; CHEUNG, 2000). Lipids appear to be low in marine algae (1-3% dry weight) (DAWES; GODDARD, 1978; DE OLIVEIRA et al., 2009; MABEAU; FLEURENCE, 1993; TABARSA et al., 2012).

Yaich et al. (2011) found 7.9% dry weight in the green seaweed *U. lactuca* collected in Tunisia. Our findings revealed that the seaweeds species primarily contributed for proteins and carbohydrates (Tables 3, 4), suggesting them as food supplements intended to reduce obesity (KUMAR et al., 2011; MAEDA et al., 2005) and heart disease risks, and in weight control (MOHAMED et al., 2012). The nutritional concern for marine macroalgae lipids is due to their low caloric value compared with other food sources (KUMAR et al., 2011; MARSHAM et al., 2007). Conversely, due to the lack of lipids (Table 5), these macroalgae species are not appreciable sources of biofuel based on Araújo et al. (2011).

Once that the development of new functional foods from seaweeds has gained special stimulus for enhancing safety and quality attributes of foods by pharmaceutical companies in recent times (CAMPO et al., 2009; GUPTA; ABU-GHANNAM, 2011), our study described four Brazilian tropical seaweeds as a potential source of food ingredients. Additional studies are in progress in order to evaluate the effects *in vivo* and of environmental conditions on the biosynthesis of the different chemical components present in Brazilian marine benthic macroalgae.

Conclusion

The Brazilian tropical seaweeds *Hypnea musciformis*, *Solieria filiformis* (Rhodophyta), *Caulerpa cupressoides* and *C. mexicana* (Chlorophyta) have different contents of water, ash, protein, carbohydrate and lipid. The red species show to contribute with ashes and lipids is in *Caulerpa* species; but, in general, their levels are in accordance with other studied algae. The most abundant components are proteins and carbohydrates, which make these seaweeds a potential source of food ingredients for diets.

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