Algal Research 33 (2018) 316–327

Contents lists available at ScienceDirect

Algal Research

journal homepage: www.elsevier.com/locate/algal

Biotechnological potential of benthic marine algae collected along the Brazilian coast

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ARTICLE INFO

Keywords:
Seaweeds
Biotechnological potential
Biochemical composition
Photosynthesis

ABSTRACT

The use of algal biomass as bioproducts source has been studied; in fact, some species produce a high amount of carbohydrates, proteins, pigments and oils, and such species could be used for the production of several products, even nutraceuticals and biofuels. To evaluate this potential, the biochemical composition of macroalgae collected along the Brazilian coast, including 14 species of Rhodophyta, 4 of Chlorophyta, and 7 of Phaeophyceae, was investigated. Photosynthesis was estimated for species belonging to the most representative orders in order to evaluate its relationship to macromolecule biosynthesis. There was a wide variation in the content of lipids, carbohydrates and proteins, and the highest values were found in the species *Dictyota menstrualis* (Hoyt) Schnetter, Hörning & Weber-Peukert, *Gracilaria mammillaris* (Montagne) M.A.Howe, and *Aglaothamnion uruguayense* (W.R. Taylor) Aponte, D.L. Ballantine & J.N.Norris, respectively. The content of phycobiliproteins was also higher in this last species. Results showed that *D. menstrualis* to be the best source for biodiesel production based on its high photosynthetic rate, high content of lipids and fatty acids, and high content of monounsaturated fatty acids. *Spatoglossum schroederi* (C.Agardh) Kützing showed a high content of polyunsaturated fatty acids and ω-3, making it interesting for nutraceutical application. A distinct pattern among the different groups of macroalgae in relation to photosynthesis and biosynthesis of macromolecules was also observed, suggesting that different strategies should be undertaken to divert algae metabolism to the production of the metabolite of interest.

1. Introduction

Benthic marine algae provide a myriad of compounds that are, for example, used in food and feed, pharmaceutical and cosmetic industries. Because of the several commercial applications and total annual revenue of *ca.* US$ 5.6 billion, their non-wild large-scale production (*e.g.*, cultivation as monoculture and Integrated Multi-Trophic Aquaculture – IMTA) has been increasing rapidly (8% per year at 2000s decade) and is present in about 50 countries [1]. Even nations that are known to sustainably harvest wild macroalgae in an industrial large-scale manner, such as Norway, are now committed to develop a bioeconomy based on cultivated macroalgae [2].

Nevertheless, the price of aquatic plants, which are dominated by macroalgae in terms of volume, devalued *ca.* 30% from 2005 to 2014 [3]. About 90% of the biomass productions are destined for human consumption [4]. However, the remaining biomasses are available for other non-food competitive market segments, clearly demonstrating a market opportunity that depends on bioprospection of new sources of potentially bioactive compounds, such as omega-3 fatty acids (specifically eicosapentaenoic acid -EPA and docosahexaenoic acid – DHA, estimated to overcome US$ 35 billion [5]).

Many macroalgae metabolites could be harnessed in a biorefinery concept, such as fatty acids, which can be used as feedstock for nutraceuticals and/or biodiesel [6,7]. Although most macroalgae present minor amounts of oils, some species are associated with expressive accumulation, such as *Dictyota acutiloba* J.Agardh and *Dictyota sandvicensis* Sonder in Kützing (Phaeophyceae), which have 16% and 20% of lipids/DW, respectively [8]. These values indicate that both species could be used for the production of oil-based compounds.

To know macroalgae's fatty acid profile is pivotal to determine whether the oil obtained is suitable for use as a source of nutraceuticals. Macroalgae with a high content of ω-3 and ω-6 could be used in this context since these polyunsaturated fatty acids play an important anti-inflammatory role, and ω-3 can act as a preventative in some diseases, such as heart diseases and hypertension [9], providing health benefits, such as prevention and treatment of diseases [10]. Not otherwise suitable for this purpose, it could be utilized for other applications, as biodiesel production. The fatty acid profile will influence the

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https://doi.org/10.1016/j.algal.2018.05.008
Received 22 May 2017; Received in revised form 29 January 2018; Accepted 12 May 2018

Table 1
Collecting data of species belonging to Rhodophyta, Chlorophyta and Phaeophyceae from the states of São Paulo (SP) and Rio Grande do Norte (RN), located, respectively, along the southeastern and northeastern Brazilian coast.

Species	Collection site	Accession number in the SP Herbarium
Rhodophyta		
Ceramiales		
Acanthophora spicifera (M.Vahl) Børgesen	Praia da Fortaleza, SP 23°53′15.6″S/45°16′35.6″W	SP 427971
Aglaothamnion uruguayense (W.R. Taylor) Aponte, D.L. Ballantine & J.N.Norris	Praia Brava da Fortaleza, SP 23°52′15.6″S/45°16′63.5″W	SP 427972
Bryocladia thyrsigera (J.Agardh) F.Schmitz	Praia Brava da Fortaleza, SP 23°52′15.6″S/45°16′63.5″W	SP 427973
Bryothamnion seaforthii (Turner) Kützing	Praia Dura, SP 23°50′15.6″S/5°17′40.5″W	SP 427974
Laurencia dendroidea J.Agardh	Rio do Fogo, RN 5°27′79.9″S/35°37′56′W	SP 427961
Palisada flagellifera (J.Agardh) K.W.Nam	Praia Dura, SP 23°50′15.6″S/45°17′40.5″W	SP 427970
Bonnemaisoniales		
Asparagopsis taxiformis (Delile) Trevisan de Saint-Léon	Praia Dura, SP 23°50′15.6″S/5°17′40.5″W	SP 427975
Halymeniales		
Cryptonemia crenulata (J.Agardh) J.Agardh	Rio do Fogo, RN 5°27′79.9″S/35°37′56′W	SP 427962
Nemaliales		
Dichotomaria marginata (J.Ellis & Solander) Lamarck	Praia da Fortaleza, SP 23°53′15.6″S/45°16′35.6″W	SP 427976
Gracilariales		
Gracilaria birdiae Plastino & E.C.Oliveira	Rio do Fogo, RN 5°27′79.9″S/35°37′56′W	–
Gracilaria cervicornis (Turner) J.Agardh	Rio do Fogo, RN 5°27′79.9″S/35°37′56′W	SP 427963
Gracilaria mammillaris (Montagne) M.A.Howe	Rio do Fogo, RN 5°27′79.9″S/35°37′56′W	SP 427964
Gigartinales		
Hypnea pseudomusciformis Nauer, Cassano & M.C.Oliveira	Praia Brava da Fortaleza, SP 23°52′15.6″S/45°16′63.5″W	SP 427377
Solieria filiformis (Kützing) P.W.Gabrielson	Rio do Fogo, RN 5°27′79.9″S/35°37′56′W	SP 427965
Chlorophyta		
Bryopsidales		
Caulerpa racemosa (Forsskål) J.Agardh	Praia da Fortaleza, SP 23°53′15.6″S/45°16′35.6″W	SP 427977
Siphonocladales		
Cladophoropsis membranacea (Hofman Bang ex C.Agardh) Børgesen	Praia da Fortaleza, SP 23°53′15.6″S/45°16′35.6″W	SP 427978
Cladophorales		
Rhizoclonium africanum Kützing	Mangue da Praia Dura, SP 23°50′15.6″S/45°17′40.5″W	SP 427966
Ulvales		
Ulva lactuca Linnaeus	Praia Dura, SP 23°50′15.6″S/45°17′40.5″W	SP 427379
Phaeophyceae		
Dictyotales		
Dictyopteris delicatula J.V.Lamouroux	Praia da Fortaleza, SP 23°53′15.6″S/45°16′35.6″W	SP 427979
Dictyota menstrualis (Hoyt) Schnetter, Hörning & Weber-Peukert	Rio do Fogo, RN 5°27′79.9″S/35°37′56′W	SP 427967
Lobophora variegata (J.V.Lamouroux) Womersley ex E.C.Oliveira	Rio do Fogo, RN 5°27′79.9″S/35°37′56′W	–
Padina gymnospora (Kützing) Sonder	Rio do Fogo, RN 5°27′79.9″S/35°37′56′W	SP 427968
Spatoglossum schroederi (C.Agardh) Kützing	Rio do Fogo, RN 5°27′79.9″S/35°37′56′W	SP 427969
Fucales		
Sargassum cymosum C.Agardh	Praia da Fortaleza, SP 23°53′15.6″S/45°16′35.6″W	SP 427378
Sargassum stenophyllum Martius	Praia Brava da Fortaleza, SP 23°52′15.6″S/45°16′63.5″W	SP 427980

macroalgae-derived oil properties as cetane number (or cetane index), iodine number, and oxidative stability, among others, and oil rich in monounsaturated fatty acids has the best features [11]. The fatty acids profile vary among different species of marine macroalgae [12], and the identification of such species within this diversity could lead to those with high oil content and a profile suitable for use as a source of nutraceuticals or biodiesel. After extracting oil-based products, the remaining biomass may be rich in protein, pigments and carbohydrates and can therefore be used as food, feed, biofuel, fertilizer, and pigment, increasing still more the economic value of the species [13]. Some macroalgae proteins have antihypertensive, antioxidant, and anticancer activities, among others [14,15]. Chlorophylls, carotenoids, and