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Research Article

Nutritional profile of some important *Caulerpa* J.V. Lamouroux species along Maharashtra and Gujarat coast, India

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ABSTRACT

Caulerpa spp are one of the abundant group of seaweeds found in intertidal areas. Nutritional content of eight specimens of different *Caulerpa spp* collected from Gujarat and Maharashtra coast were studied. Among various species, ash and carbohydrate were dominant components, highest ash (40.27 %) recorded from *C. veravalensis* and carbohydrate (40.44 %) from *C. racemosa v. macrophysa*, both seaweeds were collected from Veraval, while protein content was upto 17.19 % as in case of *C. sertularoides* from Colaba. Fatty acid profile showed maximum content of SAFA's (up to 6.34 %) followed by PUFAs (up to 42.84 %) in all the species. Seaweeds can provide protein and low fat carbohydrate content as part of a balanced diet and can be used as food source or as supplements.

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INTRODUCTION

With ever growing population, which is accompanied by increasing number of mouths to feed from same limited cultivable land, interests are given in search of alternative source of nutrition in nature. In this respect seaweeds are good source of nutrients and are already been used in many countries directly as salad, processed (dried, fermented) or as seaweed extracts in various regions of the world. Seaweeds forms a major component of food in many Asian countries like Japan, Korea and China, popularity of seaweed is spreading to Europe also (Chapman and Chapman, 1980; Pereira, 2011).

India with its long coast line provides many ideal places for seaweed growth. Many workers had studied different nutritional properties of seaweeds from India and other parts of the world. Apart from food and phycocolloid industry, algae have potential to be used as a source of long and short chain chemicals with medicinal and industrial applications. Worldwide around 221 species of algae, 125 Rhodophyta (Red algae), 64 Phaeophyceae (Brown algae) and 32 Chlorophyta (Green algae) are used for various purposes. Sea grapes or Green caviar is common name for edible varieties of *Caulerpa* spp., Bryopsidophyceae, among many species of the genus *Caulerpa*, *C. lentillifera* and *C. racemosa* are the two most popular edible ones. Both have a grape-like appearance and due to their grass-green in colour, soft and succulent texture, are usually consumed in the form of fresh vegetable or salad (Ostraff, 2006; Pereira, 2011).

Many researchers have reported several species of *Caulerpa* J.V. Lamouroux from east (Chacko *et al*, 1955; Medhi *et al.*,2009) and west coasts of India (Chennubhotla *et al.*, 1987; Untawale *et al.*, 1989[aandb]; Dhargalkar and Deshmukhe, 1996). These reports are however restricted to occurrences and distribution various species of *Caulerpa spp*. Though many species of this genus are consumed as food in different parts of the world, its nutritional qualities were not given much in India. Since this genus contributes to the largest amount of the total biomass, the present study was intended to enhance the understanding of nutritional profile of various species of Caulerpa, collected from various locations in northwest coast of India.

MATERIALS AND METHODS

Sample collection

Different species of *Caulerpa* were collected during lowest tide mark from intertidal area of Maharashtra, Malvan (lat. 16^0 03' 37.5'' N, long. 73^0 27' 21.4'' E), Colaba (lat. 18^0 54' 15.0'' N, long. 72^0 48' 08.5'' E) and Gujarat Veraval (lat. 20^0 54' 33.7'' N, long. 70^0 21' 06.0'' E), Okha (lat. 22^0 28' 48.2'' N, 69° 04' 50.9'' E). All specimens were collected from exposed areas of intertidal region during low tide. The collected samples were washed with seawater and cleaned of attached debris and other foreign matter. The seaweeds were then air dried under room temperature (25 ^{0}C) for 24h and then under forced convection at 40 ℃for 15 min.

Biochemical composition analysis

Biochemical proximate composition of the different species of *Caulerpa* was analysed as per the prescribed methods of AOAC (1995) for moisture, ash, crude protein, crude lipid.

Extraction of lipids and Fatty Acid analysis

Extraction of lipid from the dried seaweed samples was done by the method of Bligh and Dyer (1959) with slight modifications. Finely ground dried seaweed sample was added to a mixture of distilled water, methanol and chloroform (1:3:1.5) in a beaker and mixed for 30 seconds with tissue homogenizer. Again chloroform and distilled (1:1) water was added and mixed for 30 seconds. The mixed solution was then filtered into a separating funnel and kept for 6 hours for separation of upper and lower layers. Lower layer was then collected in a pre-weighed flat bottom flask and the organic solvent was evaporated using a rotary evaporator. Weight of flask with lipid was taken and weight of lipid was calculated from the difference in the weight of the flask with lipid and empty flask. The AOAC (1995) method was followed to esterify the lipid extract. Fatty acid methyl esters (FAME) was prepared from the lipids extracted from the seaweed sample by heating with the methanolic NaOH first and then with BF3 Methanol for esterification. 5 ml n-heptane was added to recover the methyl esters in organic phase. Saturated NaCl solution was added to the mixture and the aqueous and organic were separated using a separating funnel. The upper n-heptane phase was pipetted out and stored in 10 ml glass vials in refrigerator until further analysis. Fatty acids were separated by using a Shimadzu QP2010 quadrupole Gas Chromatography Mass Spectrometer (GC-MS) instrument equipped with a Carbowax (30 m x 0.25 mm ID; 0.25-µm film thickness) capillary column (Cromlab S.A.). Helium was used as the carrier gas. Injector and detector temperatures were set at 250°C. Injection was performed in split mode (1:15). The column temperature was programmed initially at 50°C for 2 min and then to increase at a rate of 10°C per min to a final temperature of 230°C. FAM esters were separated at constant pressure (23.1 kPa) and peaks were identified by comparing the mass spectra with the mass spectral data base.

Statistical analysis

All data are expressed as mean ± standard error (n = 3). Data were analyzed using one-way analysis of variance (ANOVA) using Microsoft Office Excel 2007 (Microsoft, USA). A significant difference was considered at the level of $p < 0.05$.

RESULTS AND DISCUSSION

A total of eight samples belonging to 7 *Caulerpa* spp were collected from four different sites (Table 1). *C. purvula* and *C. taxifolia* collected from Malvan, *C. sertularoides* from Colaba, while *C. scalpelliformis v. denticulata*, *C. racemosa v. macrophysa* and *C. veravalensis* from Veraval and *C. microphysa* and *C taxifolia* from Okha. The selection was based on abundant species among various *Caulerpa spp* in sampled site.

Table 1 illustrate the nutrient compositions of various *Caulerpa spp*. There is distinct variation in nutritional content between species of different sites. Protein content was highest (17.19 ± 1.01) in *C. sertularoides* collected from Colaba followed by *C. scalpelliformis v. denticulata* (16.85 ± 0.25) from Veraval and least protein was found in *C. racemosa v. macrophysa* (9.21 ± 0.53) from Veraval. Green seaweeds tend to contain more protein than brown seaweeds, but highest levels were found in Red seaweed (eg *Porphyra tenera* 28-4 %) (Pereira 2011). Other similar studies on *Caulerpa* recorded protein content at 10.5 % and 12.8% in *C. scalpelliformis v. denticulata* and *C. racemosa* collected from Veraval Coast (Kumar *et al.,* 2011a). Variation among species may is not just attributed to season and location but also depends on basic nutrients availability in water, which intern is converted in to seaweed growth (Manivannan, *et al*., 2008), as seen in protein content of *C. taxifolia* (18.3 %) collected from Okha (Naidu, *et al*., 1993) while in present study it was 15.2 % for Okha specimen and 16.33 % in Malvan one.

In general seaweeds are known to contain low lipid (Dawes, 1998) the statement is validated in present study as crude lipid in all collected specimens was low (<3 % DW) and there was no significant difference ($P \leq 0.05$)). Highest lipid content was observed in *C. taxifolia* (2.44 %) collected from Okha and *C. sertularoides* (2.32 %) from Colaba. Lowest level was seen in *C. racemosa v. macrophysa* (1.39 %) from Veraval followed by *C. purvula* (2.33 %) from Malvan. Similar kind of low lipid content was observed in other seaweeds like *Porphyra sp* (1-2.8 %) (Dawczynski, *et al*., 2007), *Cladophora sp* (1 %) *Ulvalactuca* (0.5 %) (Marsham *et al*., 2007).

Ash is the abundant component among studied specimens, values ranging from lowest 23.90 % (*C. scalpelliformis v. denticulata*) to highest 40.2 % (*C. veravalensis*) both from collected from Veraval. *C. racemosa v. macrophysa* ash content was significantly different with that of other specimens studied (Table 1). Similar ash content was observed in *C. scalpelliformis v. denticulata* (40.77 %) (Kumar, *et al*., 2011a), *C. taxifolia* (35.4 %) (Naidu, *et al*., 1993) and *C. lentillifera* (24-37 %) (Pereira, 2011). Kumar, *et al*., 2011a reported that higher ash content indicates presence of diverse minerals, hence sea weeds can also act as good source of dietary minerals (Naidu, *et al*., 1993).

Carbohydrate formed another high concentrated component among studied *Caulerpa* spp, highest value observed in *C. racemosa v. macrophysa* (40.44 %) from Veraval, followed by *C. microphysa* (39.5 %) and *C. taxifolia* (38.2 %) both from Okha. Lowest level of carbohydrate was recorded in *C. taxifolia* (31.0 %) from Malvan. Similar values were observed in *C. taxifolia* (35.1 %) (Naidu *et al*., 1993) and *C. racemosa* (33-41 %) (Pereira, 2011).Carbohydrate formed another high concentrated component among studied *Caulerpa* spp, highest value observed in *C. racemosa v. macrophysa* (40.44 %) from Veraval, followed by *C. microphysa* (39.5 %) and *C. taxifolia* (38.2 %) both from Okha. Lowest level of carbohydrate was recorded in *C. taxifolia* (31.0 %) from Malvan. Similar values were observed in *C. taxifolia* (35.1 %) (Naidu *et al*., 1993) and *C. racemosa* (33-41 %) (Pereira, 2011).

Table 1: Nutrients of various *Caulerpa spp* collected from different locations (mean ± SE, n=3)

Nutrients (% DW)		Moisture	Crude Protein	Crude Lipid	Ash	Total carbohydrate
Site	**Species**					
Malvan	*C. purvula*	19.97 ± 1.39[a]	12.86 ± 0.86[a]	1.33 ± 0.29[a]	31.37 ± 1.73[a]	34.47 ± 1.94[ab]
	C. taxifolia	24.34 ± 1.08[ab]	16.33 ± 0.86[a]	1.89 ± 0.40[a]	26.37 ± 1.04[a]	31.07 ± 0.90[ab]
Colaba	*C. sertularoides*	12.97 ± 0.88[a]	17.19 ± 1.01[a]	2.32 ± 0.43[a]	34.63 ± 1.10[a]	32.88 ± 2.97[a]
Veraval	*C. scalpelliformis v. denticulata*	21.14 ± 0.27[b]	16.85 ± 0.25[b]	1.83 ± 0.18[a]	23.90 ± 0.81[a]	36.28 ± 0.98[ab]
	C. racemosa v. macrophysa	18.11 ± 0.36[a]	9.21 ± 0.53[a]	1.29 ± 0.19[a]	30.95 ± 0.37[b]	40.44 ± 0.90[ab]
	C. veravalensis	13.79 ± 0.37[a]	11.02 ± 0.45[a]	2.17 ± 0.23[a]	40.27 ± 0.64[a]	32.76 ± 0.72[b]
Okha	*C. microphysa*	12.30 ± 0.40[a]	13.83 ± 0.69[a]	1.58 ± 0.20[a]	32.71 ± 1.30[a]	39.57 ± 0.43[b]
	C. taxifolia	18.99 ± 0.69[a]	15.27 ± 0.35[a]	2.44 ± 0.39[a]	25.04 ± 0.87[a]	38.26 ± 0.45[b]

(*P≤0.05) means bearing same superscript with in row are not significantly different.

Table 2: Fatty acids composition in % TFA of three *Caulerpa* species (mean ± SE, n =1)

Sites	Colaba		Malvan	Veraval			Okha	
Fatty acids / Species	*C. purvula*	*C. taxifolia*	*C. sertularoides*	*C. scalpelliformis v. denticulata*	*C. racemosa v. macrophysa*	*C. veravalensis*	*C. microphysa*	*C. taxifolia*
SAFA								
C12:0	n.d.	n.d.	n.d.	n.d.	0.20	n.d.	0.17	n.d.
C13:0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C14:0	3.74	2.45	n.d.	1.90	2.52	2.22	4.13	3.84
C15:0	n.d.	0.92	1.10	0.20	n.d.	n.d.	n.d.	n.d.
C16:0	50.19	47.24	51.02	44.08	70.54	52.09	48.85	38.32
C17:0	n.d.	n.d.	1.82	0.16	n.d.	0.40	n.d.	n.d.
C18:0	1.18	2.32	0.27	1.83	3.08	4.17	6.22	4.12
C20:0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C22:0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C24:0	n.d.	3.62	n.d.	2.06	n.d.	n.d.	n.d.	0.20
MUFA								
C14:1	n.d.	2.86	n.d.	n.d.	n.d.	n.d.	n.d.	0.12
C16:1 (n-7)	3.07	7.34	0.32	2.05	3.72	2.38	2.21	4.45
C17:1 (n-7)	n.d.	n.d.	n.d.	0.32	n.d.	0.15	1.05	0.13
C16:1 (n-9)	n.d.	n.d.	0.10	1.04	0.47	n.d.	n.d.	n.d.
C18:1 (n-9)	6.81	4.83	1.02	2.38	5.03	3.35	6.48	8.13
C18:1 (n-5)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
C20:1 (n-9)	4.26	6.78	1.51	1.17	0.15	2.05	1.52	8.30
C22:1 (n-9)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

PUFA								
C16:2 (n-5)	3.16	2.52	n.d.	n.d.	n.d.	n.d.	n.d.	0.15
C18:2 (n-5)	n.d.	n.d.	5.82	n.d.	n.d.	n.d.	n.d.	n.d.
C18:2 (n-6)	12.60	4.26	6.58	24.32	7.08	17.08	9.36	8.64
C20:2 (n-6)	n.d.	n.d.	n.d.	0.81	0.25	0.18	0.62	n.d.
C18:3 (n-6)	2.18	n.d.	3.44	4.18	n.d.	n.d.	n.d.	n.d.
C18:3 (n-3)	4.04	5.47	12.61	6.07	n.d.	5.26	6.59	9.87
C20:3 (n-3)	n.d.	n.d.	n.d.	4.03	n.d.	n.d.	n.d.	n.d.
C20:4 (n-6)	2.42	4.83	6.71	3.20	2.04	4.78	5.87	6.93
C20:5 (n-3)	6.20	4.56	7.68	n.d.	4.73	5.57	6.82	6.68
C22:6 (n-3)	0.15	n.d.	n.d.	0.20	0.20	0.32	0.11	0.12
SAFA	55.11	56.55	54.21	50.23	76.34	58.88	59.37	46.48
MUFA	14.14	21.81	2.95	6.96	9.37	7.93	11.26	21.13
PUFA	30.75	21.64	42.84	42.81	14.29	33.19	29.37	32.39

TFA, total fatty acid; SAFA, MUFA and PUFA represents saturated, monounsaturated and polyunsaturated fatty acids respectively

Fatty acid composition

Percent distributions of fatty acids isolated and identified from *Caulerpa spp* is presented in Table 2. Saturates contributed to major portion of the total 46.48 % in *C. taxifolia* collected from Okha to 6.34 % in *C. racemosa v. macrophysa* from Veraval, among all *Caulerpa spp* investigated hexadecanoic acid was dominant saturated fatty acid representing 38.32 to 70.54 %, next dominated with a lesser extent were stearic acid followed by myristic acid. Similar trend of higher (45.2-73.6 %) saturates was observed in *C. taxifolia* throughout the year (Iveša, *et al*., 2004). Polyunsaturated fatty acids (PUFA) formed next dominant group with highest value observed in *C. sertularoides* (42.84 %) and *C. scalpelliformis v. denticulata* (42.81), while lower in *C. racemosa v. macrophysa* (14.29 %) and *C. taxifolia* (21.69 %) from Colaba. Among PUFA Linoleic Acid was dominant and found in all *Caulerpa spp* studied. Chlorophytes studied by (Kumar, *et al*., 2011b) had higher ratios of PUFA/SFA (>0.4) with permissible intake values as recommended in nutritional guidelines (Wood *et al*., 2004).

C. microphysa and *C. racemosa v. macrophysa* are been consumed in different parts of world (Indy, *et al*., 2014). Based on the current study it can be concluded that, many *Caulerpa spp* can provide protein and low fat carbohydrate content as part of a balanced diet as mentioned by Yuan and Walsh 2006. As many of studied *Caulerpa spp* contained good amount of fatty acids, especially PUFA-SAFA ratio, increased intake of these fatty acids are known to be associated with a lower risk of human coronary heart disease. Many of the studied *Caulerpa spp* have potential of being used as food source or as supplements.

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