Chemical composition of six edible seaweed species available in the coastal belt of Sri Lanka

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Abstract

Climatic and hydrographic conditions allow several genera of seaweed species to grow along coastal belt of Sri Lanka. They are classified as green, brown and red algae depending upon the type of pigments present and other morphological and anatomical characters. Polysaccharides, extracted from seaweeds; agar, carrageenan, and alginates contains several nutritional compounds which are important substitutes used in food, agriculture and medicinal industry. Seaweeds were collected from Northwestern and Southwestern coastal belt of Sri Lanka. Samples were washed, cleaned, air dried, packed in air tight containers and kept in 4°C in powdered form until analysis. The results show that red seaweed contains higher calcium than green and brown algae. Also brown and red seaweeds exhibited higher averages of sodium and potassium than that of green species. Significantly highest content of Na and K were recorded ($P<0.001$) in brown algae (*Sargassum wightii)* and in decreasing order in *Ulva lactuca*, *Gracilaria eduli* and *Kappaphycus alvarezii.* The green seaweeds showed the highest magnesium content than red and brown algae; ranging from 14.920-18.016 g/kg. Nickel (0-0.013 g/kg), manganese (0.006-0.188 g/kg) and boron (122-539 mg/kg) were recorded in high constitutes. The micro elements cobalt and chromium were not found in any of the seaweed species. The results of average proximate constitutions of different species are as follows: Carbohydrates: 56.9, 52.49, 53.5%, Protein: 11.83, 10.80, 9.25%; Ash: 2.70, 2.7, 2.78% and, Moisture: 24.67, 27.4, 23% in red, green and brown algae respectively. The nutritional evaluation shows that the mineral composition depends on the seaweed species. The mineral contents of seaweeds were significantly higher than vegetables such as soya bean white and lettuce. Therefore, these seaweed species could serve as a source of essential mineral to improve nutritional value of human diet.

Keywords: Nutrients, Seaweed, Polysaccharide, Macro and micro elements

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Introduction

Marine seaweed comprises few thousands of species and they represent a considerable part of the littoral biomass. According to their nutritive value and chemical composition, they are classified into red (Rhodophyta), brown (Phaeophyta), and green (Chlorophyta) seaweeds (Dawezynski *et al*., 2007). Extensive researches have been conducted on culinary use of seaweeds and there is an increasing trend to develop health conscious products from seaweeds.

Culture of seaweed species are found to be feasible, while natural stocks such as *Gracilaria* species are largely exploited for the export purposes. *Gracilaria* is seasonally abundant in Sri Lanka and use for domestic consumption and export in dried form. *Kapphaphycus alvarezii* is cultured in commercial scale at present. In Sri Lanka nutritional value studies (metallic consumption) of seaweeds on the context of human food are scanty. Records on certain edible seaweeds showed that several seaweed contain significant amounts of carbohydrates, proteins vitamins and minerals which are essential for human nutrition deficiencies (Jensen, 1993).

The nutritional composition of seaweed varies and is affected by species, geographic area, season and temperature of water (Mohd and Chio, 2000). These seaweeds are of nutritive and low calorie food, but rich in vitamins, mineral and dietary fibers (Ito and Hori, 1989). The mineral fractions of some seaweeds account for up to 40% of dry matter (Ortega *et al*.,1993). However in some cases the mineral content of the seaweed is recorded higher than that of terrestrial plants and animals. Seaweed consumption is at an increasing rate estimated to be about 25% of seaweed out of all the food consumed (Ito and Hori, 1989). However, Seaweed contain 80-90% water in dry weight, contains 50% carbohydrates, 1-3% lipids, and 7-38% minerals. The protein contents are highly variable (10 – 47%) with high proportion of essential amino acids.

In view of current increasing demand for seaweed products, the research was focused to study the nutritional value of some locally available seaweed species to introduce as a source of major nutritional ingredients into food. Comparative evaluation of nutritional value with commonly consumed locally available land vegetables were also gathered.

Materials and Methods

The four seaweed species *Sargassum wightii, Ulva reticulata, Ulva lactuca, K. alvarezii* were collected from Southwestern costal belt. The *Gracilaria edulis* and *Gracilaria verrucosa* were collected from natural beds on the North coast. The samples were kept in ice and transported to the laboratory of Institute of Post Harvest Technology, NARA and washed with running water and dried in an air circulated oven. Appropriate amounts of the dried samples were taken, cut, ground into smaller pieces and kept in plastic containers covered with aluminum foil. Samples were kept at 4^0C for further analysis.

Proximate composition of six seaweed species were determined (AOAC, 1995). Macro and micro elements were also tested (AOAC 1995). The samples were used to determine minerals contents of Co, Ni, Cr, Mn, K, Mg, Ca, Na, B and sulphates. Dried fine powdered seaweed samples (1g) were completely microwave digested using Teflon cups with 10 mL 99% HNO_3. All digested solutions were analyzed in triplicate using Atomic Absorption Spectrophotometer (Australia, varian 240) for metal determination. Triplicates were maintained for each experiment and mean value was expressed as g/kg of algae dry weight. The statistical analysis was done according to software package SPSS version 22 (SPSS, 2016).

Results and Discussion

Essential metals

Table.1 shows the mineral content of the six seaweed species and two vegetables; lettuce and spinach. The Mg content was found to be highest in *U. lactuca* (18.016 ±0.234 g/kg) while lowest 4.447±0.35 g/kg was found in *G. verrucosa.* The lettuce having the lowest value 0.0609 g/kg and spinach 0.54 g/kg among the vegetables. The Mg content in seaweeds was tenfold higher than the lettuce (McCance *et al.*, 1993).

The Acceptable Daily Intake (ADI) for Mn is 69.2 ppm (Venkateshwarlu *et al.*, 2014). The Mn levels in *G. edulis* and *G. verrucosa* were beyond the ADI value. The maximum Mn concentrations was found in the *G. verrucosa* (0.188± 0.13 g/kg) while minimum was in the *Kappaphycus* 0.0064±1.3 g/kg. The values found in seaweeds were higher than the vegetables. Among vegetables, spinach and lettuce had closer values of 0.013 and 0.01 g/kg respectively (McCance *et al.*, 1993).

Table 1. Mineral content (in g/kg) six seaweed species available in Sri Lanka

Parameter (g/kg)	*G. edulis*	*G. verrucose*	*S. wightii*	*U. lactuca*	*U. reticulate*	*K. alverazii*
Co	ND	ND	ND	ND	ND	ND
Ni	ND	0.013±0.89	ND	ND	ND	ND
Cr	ND	ND	ND	ND	ND	ND
Mn	0.128 ± 0.86	0.188 ± 0.13	0.006 ±1.6	0.011±0.73	0.009 ± 2.9	0.0064±1.3
K	15.397±-0.35	2.65 ±0.286	72.909±.845	15.882±0.678	14.678±0.367	69.299±0.246
Mg	5.901±-0.075	4.447±-0.35	5.453±0.6348	18.016±0.234	14.920±0.432	6.026±0.320
Ca	79.018±-0.550	4.000±0.056	9.504±0.780	15.741±0.312	12.890±0.231	2.146±0.210
Na	3.121±-0.00065	1.415 ± 0.00098	19.347±0.123	11.566±0.214	11.230±0.125	17.952±0.31
B mg/L	122±21	ND	235±46	ND	ND	ND
Sulphates (g/kg)	35.0± 0.00076	46.5± 0.00025	5.6±.00097	47.0±0.00076	6.6±0.1345	67.9±0.145

Mean± S.E. , n=3, ND = Not Detected

The brown seaweed *S. wightii* showed the highest K content 72.909±0.845 g/kg followed by 69.299±0.246 g/kg in *K. alvarezii.* Thus, the brown seaweed has higher K than red and green seaweeds. *G. verrucosa* has lowest K level 2.65±0.286 g/kg compared to other seaweeds. The highest value was showed in spinach 5.0 g/kg among vegetables (McCance *et.al*., 1993). It was mentioned that marine seaweed contains predominantly Na and their salts. Some seaweed accumulates more K and their salts than Na (Krishnaiah *et al*., 2008). However, K is an essential element for the growth and metabolic activities of plants and seaweeds (Sivakumar and Arunkumar, 2009). The K level in seaweeds was not far higher than the Recommended Daily Adults Intake (2,000 mg/day). The 8 g of *U. lactuca* provides 127 mg/day of potassium requirement of diet.

The Calcium content was found highest in red seaweed *G. edulis* 79.018±0.55 g/kg followed by green *U. lactuca* 15.741±0.312 g/kg (Table.1).The lowest value 2.146 ±0.21 g/kg was observed in *K. alvarezii.*

Among the two vegetables, lettuce has thousand times lower calcium levels than that in *G.edulis.* Seaweeds are high in minerals due to their marine habitats, and the diversity of the minerals they absorb is wide (Mohd *et al*., 2000). Important minerals such as calcium accumulate in seaweed at much higher levels than in terrestrial plants. Committee on Medical Aspects of Food and Nutrition Policy, (1991) stated that 8 g portions of *U. lactuca* (sea lettuce), which provides 260 mg of calcium, equaling approximately 37% of the Recommended Nutrition Intake (RNI) of calcium for an adult male (1,200 mg/day).

The brown seaweed *S. wightii* has highest average Na level of 19.347±0.123 g/kg and *K. alvarezii* has 17.952±0.31 g/kg level of Na. *U. lactuca* contains Na value of 11.566±0.214 g/kg. The lowest value 1.415 g/kg was found in *G. verrucosa*. The level of Na in raw green seaweed were found significantly higher ($p > 0.05$) than the recorded values for vegetables such as lettuce 0.1 g/kg and spinach 1.4 g/kg as shown in table 2. (McCance *et al*., 1993).

Table 2. Mineral composition (in g/kg) of two vegetables (territorial) (Mean ± S.E.)

Parameter (g/kg)	Spinach	Lettuce
Cobalt (Co)	ND	ND
Nickle (Ni)	ND	ND
Chromium (Cr)	ND	0.08±0.002
Manganese (Mn)	0.013 ± 0.5	0.010±2.50
Potassium (K)	5.0±0.67	1.410±0.56
Magnesium (Mg)	0.540±0.54	0.0609±0.78
Calcium (Ca)	1.700± 0.3	0.018±0.40
Sodium (Na)	1.400± 0.5	0.100±0.30

Source: Values from vegetables, McCance *et al*., 1993

Na and K has a strong correlation (r=0.45, p.05) as they play an important role in the electrolyte balance (Krishnaiah *et al*., 2008) and Na: K ratio should be below 1:5 (Paul *et al*., 2007). The present study revealed that (Table 3) Na and K are also relatively high and the ratio is below 1:5. The Na/K balance is regarded to be important for people who take diuretics, to control hypertension and suffer from excessive excretion of potassium (Cutler, 2006). These elements are also important as constituents of bones, teeth, soft tissues, hemoglobin, muscle, blood, and nerve cells and are vital for overall mental and physical well being (Kuda and Ikemori, 2009; Miyake *et al*., 2005). The high K and low Na were recorded in red, brown and green algae. These findings were similar to the Sivalingam, (1978). These conditions were salt inclusion and/or exclusion mechanisms in operation to avoid or tolerate the high salinity in marine organisms (Sivakumar and Arunkumar, 2009).

The highest sulphate content was found in *K. alvarezii* (67.9±0.145 g/kg) while minimum sulphate content was recorded in *S. wightii* (5.6 ± 0.097). The findings of Sivakumar and Arunkumar (2009) were similar to the observations of present study;

higher sulphate content in red and green seaweeds while minimum sulphate content was recorded in brown seaweed.

Trace elements

Adult Daily Intake (ADI) limit of Co is 8 ppm (Venkateshwarlu *et al*., 2014). Co is not detected in the any of the seaweed species studied in this research. Among all edible algae species in the study, Ni was found in *G. verrucosa.* ADI limit for the Ni is 1.8 ppm (Table.1). *G. verrucosa* having higher concentration 13±0.89 mg/kg than ADI limits. Aa shown in the table 2, spinach and lettuce are free from Ni (McCance *et al*., 1993). Cr is a toxic metal (Veakateshwarlu *et al*., 2014). Its permissible limit is 1.54 ppm. Cr was not detected in any seaweed species. B was detected in 235±46 and 122±21 mg/kg *S. wightii* and *G. edulis* respectively.

Table 3. The mean values of Na, K and Na/K ratio of seaweed collected along Southwest costal belt.

Seaweeds	Na (mg/kg)	K (mg/kg)	Na:K
Rhodophyceae (Red)	7,496	29,115	0.25
Phaeophyceae (Brown)	19,347	72,909	0.26
Chlorophyceae (Green)	6,344	15,280	0.42

Proximate composition

Proximate composition of six seaweed species, soya bean and lettuce are given in Table 4 and 5. The highest protein content is observed in *G. edulis* followed by *G. verrucosa* and *U. lactuca.* The protein content in most *Gracilaria* species are between 7 and 13% (Briggs and Smith, 1993), similar to the results obtained from the present study in the average of 11.87%. The protein values are not significantly different among the six seaweed species ($p>0.05$). The present study is similar to the investigation of Yada (2004), in the same range of protein recorded in the green and red seaweeds. However protein content was varied not only between species but also between seasons (Fleurence, 1999). The protein content of seaweed species is lower than that of soya bean and slightly higher than that in lettuce (Tee *et al*., 1988).

Table 4. Proximate composition of six seaweeds species available. (Mean± S.E.)

Parameters(%)	*G. edulis*	*G.verrucosa*	*U. reticulata*	*U. lactuca*	*S. wightii*	*K. alverazii*
Protein	11.9±0.06	11.9±0.78	9.86 ± 0.67	11.75±2.7	9.25±1.89	10.5±1.6
Carbohydrate	52.8± 1.30	53.9± 0.23	46.9± 0.56	58±0.45	53±7.8	59 ± 0.76
Fat	0.3 ± 0.67	0.1 ± 0.80	0.28 ± 0.45	0.6±0.87	0.5±0.045	0.3±0.56
Ash	2.75 ±0.89	2.4 ± 0.46	2.70± 0.32	2.75±0.43	2.78±0.89	2.97±0.67
Moisture	25.3±0.56	25.7±0.34	24.3±0.32	30±0.69	23±0.68	22±0.67

Mean±S.E.= Mean value of replicates ± Standard Error.

Lipids are rich in C=O bonds, providing much more energy in oxidation processes than other biological compounds (Bhuvaneswari and Murugesans, 2013). They constitute convenient storage materials for living organisms. In general, seaweed exhibit low lipid contents (Dave and Parek, 1975) in micro algae, the lipids are widely distributed, especially in several stages. The total lipid content in six algae species were found relatively low. *U. lactuca* showed highest (0.6±0.87%) amount of lipids among seaweeds while in *G. verrucosa* it was lowest (0.1±0.8%). The lipid values weren't significantly different among the six seaweed species. The lipids in seaweeds were comparatively very low than soya bean which was recorded the highest lipid content 18.93% (Tee *et al.*, 1988).

The highest carbohydrate content was found in *K. alvarezii* (59 ±0.76%) and followed by *U. lactuca* (58 ±0.45%) whereas the lowest value found in *U. reticulate* (46.9 ± 0.56%). The carbohydrate content was significantly different among six different seaweed species ($p<0.05$). The findings were similar to Ghada and Amany, 2012, which recorded more than 50% carbohydrate content in seaweeds. The differences in carbohydrate in the algae may be observed due to extensive growth of thallus of algae. C:N ratio and protein values in U. reticulata showed inverse relationship (Dhargalkar, 1979). These variations may attribute to the differences in species habitat and metabolic preference (Padua *et al.*, 2004).

The ash content of the seaweeds had ranged from 2.4±0.46-2.97±0.67% which indicated lower values comparable to soya bean (Tee *et al.*, 1988). Highest ash content was found in *K. alvarezii* followed by *S. wightii.* The lowest ash content was recorded in the vegetable lettuce (Tee *et al*., 1988) and it was comparable with *G. verrucosa*. There weren't significant difference between ash content of different seaweeds species. Ash content was indicated by all the seaweed and the values were comparable with soya bean.

Moisture in the air dried seaweeds range from content of 22± 0.67 – 30± 0.69% Lettuce indicated 48% moisture content (Tee *et al*., 1988) whereas soya beans exhibited 20%.

Table 5. Proximate composition of Soya bean and Lettuce

Parameters	Soya bean%	Lettuce%
Protein	33.8	1.2
Carbohydrate	50.5	51.6
Fat	18.9	0.1
Ash	4.8	0.7
Moisture	20	40

Source: Values from vegetables Tee *et al.*, (1988)

Conclusion

S.wightii (Phaeophyceae) is the most abundant source of Mg, K, and Na followed by *G. species* (Rhodophyceae) and *Ulva species* (Chlorophyceae) and meet the daily requirements of minerals in vegetable diets compared to land vegetables. All of the analyzed seaweed species are free from Co and other toxic element Cr. Consumption of small portions of seaweed mixed food per day from edible seaweeds meets requirements of mineral deficiency in the human body. In respect to proximate study of seaweed species, they contain considerable amounts of carbohydrates, ash, fat and protein. The comparison studies of seaweed species with selected vegetables indicates that seaweeds have potential of being good source of protein and carbohydrate. As macro and micro elements are abundant in seaweeds, it could be used in vegetarian food products and as a source of nutrient supplement in food and pharmaceutical industry, in medicine and fine chemical synthesis.

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