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Nutritional composition of edible seaweed *Gracilaria changgi*

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Abstract

Gracilaria changgi, an edible seaweed was analyzed to determine its proximate chemical composition, mineral elements, vitamin C, β-carotene, free fatty acid and amino acid contents. *G. changgi* showed vitamin A activity of 865 μg rectinol equivalents/100 g sample. It contained a higher composition of unsaturated fatty acids (74%), mainly the omega fatty acids and 26% of saturated fatty acids (mainly palmitic acid) and also relatively high levels of calcium and iron. Major amino acid components are glycine, arginine, alanine and glutamic acid. Among the essential amino acids assayed, lysine with a chemical score of 53% appeared to be the most limiting when compared with the essential amino acid pattern of egg protein. This study was conducted to create a nutritional data for *G. changgi* in order to popularize its consumption and utilization in Malaysia. Comparisons to corresponding nutrient values in several commonly consumed local vegetables were also made.

Keywords: Nutritional composition; Seaweed

1. Introduction

Among the major edible seaweeds of the red algae type are *Porphyra*, *Palmaria*, *Gracilaria*, *Gelidium* and *Eucheuma* (McLachlan, Craigie, Chen & Ogetze, 1972). Red algae such as *Gracilaria changgi* mainly serve as a raw material from which agar or carrageenan are extracted out for use in the food industries or in the production of tissue culture media (Glickman, 1987; Jahara & Phang, 1990). It is one of the more abundant agarophytic seaweeds found in Malaysia and is now cultured mainly for agar production (Phang, Shaharuddin, Noraishah & Sasekumer, 1996). Reports on certain edible seaweed showed that many contain significant amounts of protein, vitamins and mineral essential for human nutrition (Jensen, 1993; Noda, 1993; Oohusa, 1993). Fresh and dried seaweeds are extensively consumed especially by people living in the coastal areas. Depending on the type of species, seaweed is generally suitable for making cool, gelatinious dishes or concoctions. The nutrients composition of seaweed vary and is affected by species, geographic area, season of the year and temperature of water (Jensen). These sea-vegetables are of nutritional interest as they are low calorie food, but rich in vitamins, minerals and dietary fibres (Ito & Hori, 1989). Seaweed as a food in Malaysia is not as common as in countries like Japan and China. About 25% of all food consumed in Japan consists of seaweed prepared and served in many forms and has become the main source of income for the fishermen there. However, at present this seaweed is only consumed in certain coastal areas especially along the east coast of Peninsula Malaysia and in East Malaysia, where it is occasionally eaten as a salad dish.

Many studies on *Gracilaria* sp have been reported especially on its taxonomy and habitat characteristics (Critchley, 1993; Santelices & Doty, 1989). Studies on biochemical composition of other species of edible seaweed have been reported by Guerin and Bird (1987) and Hurtado-Ponce and Umezaki (1988). Other reports are mainly on other species and on the characteristics of the shape and type of species and relationship on growth of alga with respect to the environment. *Gracilaria* sp. was reported to contain carotenoid pigments which are important in shrimp and fish diets (Briggs & Smith, 1993). To our knowledge, the nutritional composition of *G. changgi* has not been determined and a nutritional data on this red algae is not yet available. Thus, the aims of this work were to determine the nutritional and biochemical composition of *G. changgi*.

This paper presents data on the nutrients composition of *G. changgi* i.e. proximate composition (total protein,

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total lipid, fiber and ash), minerals, β-carotene, vitamin C, free fatty acids and amino acids contents. This work also reports a comparative evaluation of the nutritional value of *G. changgi* with that of some locally consumed vegetables. The protein nutritional quality of *G. changgi* was also estimated from its amino acid composition by determination of the chemical score. The potential of *G. changgi* as a source of food nutrients is discussed.

2. Materials and method

2.1. Collection of samples

The *G. changgi* seaweeds were collected from culture ponds at Fishery Research Institute in Ban Merbok, Kedah, located on the west coast of Malaysia. The samples taken were washed in running water and freeze dried. For most of the analyses, dried samples were used except for analysis of vitamin C and fatty acids composition where fresh samples were used. Appropriate amounts of the dried samples were taken, cut, ground into smaller pieces and kept in plastic containers covered with aluminium foils. Inert nitrogen gas was passed into the containers and samples were kept at −5°C for further analysis. Samples for vitamin C and fatty acids analyses were taken immediately from the culture tanks and analysed. Since ascorbic acid is a highly unstable vitamin, it is sensitive to alkalis and to oxidation, the sampling, grinding and extraction were carried out with minimum delay.

2.2. Analytical methods

2.2.1. Proximate/biochemical analysis

Total nitrogen, fiber, ash and lipids contents in *G. changgi* were determined by standard AOAC (1990) methods. Protein content was determined by the micro-Kjeldahl method system ($N\times6.25$). Total lipid was determined according to the standard Marjonier method. The ascorbic acid content in *G. changgi* was determined using the titrimetry as described in AOAC method no:967.21 (AOAC, 1990). Some of the precautions taken for analysis of vitamin C were to perform the procedure in the presence of stabilising acid, i.e. 5% metaphosphoric acid since 5–6% of metaphosphoric acid is not only a good extractant for vitamin C but can also stabilize it for a limited period by complexing metal ions and minimising the rate of oxidation as indicated in the literature. The titrations were performed rapidly. The samples to be analyzed were not highly intensed colored solutions, thus determination of the end point were not difficult. Recovery experiments were performed by spiking standard ascorbic acids in the samples for extraction and titration. Triplicate determinations were performed for each nutrient analysis.

2.2.2. Extraction of β-carotene

β-carotene was extracted following the method described by Hart and Scott (1995) with some modifications. In this method triplicate samples of approximately 5 g were taken for β-carotene extraction. The samples were extracted with tetrahydrofuran/methanol (1:1, THF:MeOH) followed with petroleum ether (40–60°C) and antioxidant, 0.1% butylated hydroxytoluene (BHT). During the extraction, 10% NaCl was added to give a better separation between the organic and aqueous phase. The aqueous phase was extracted twice with peteroleum ether and the washings were added together. Saponification was performed with addition of 40% KOH/MeOH to the extract, with a flow of nitrogen gas and was kept in the dark at room temperature for an hour. Saponification eliminated chlorophyll pigments and hydrolyzed carotenoids esters which would interfere in the HPLC chromatographic process. The carotenoid was extracted from the KOH/MeOH phase with petroleum ether and washed with distilled water until pH was neutral. The extract was dried by rotatory vacuum evaporation and was diluted again with petroleum ether and dichloromethane to a volume of 5 ml. β-carotene content in the sample extract was determined by reverse phase high performance liquid chromatography (HPLC) method. Recovery experiments were also performed in which standard solution of β-carotene was added to the tested sample.

2.2.3. High performance liquid chromatography separation of β-carotene

Quantitative analysis on the amount of β-carotene present was performed using HPLC with a reverse phase column, Waters μ-Bondapak C_{18} column (30 cm×3.9 mm i.d.) operated at 30°C. The column was preceded by a Waters Guard-Pak pre-column module housing a disposable Guard-Pak pre-column insert packed with the same material as that in the analytical column. A Waters 510 pump was used to deliver the mobile phase which was a ternary mixture of acetonitrile, methanol, dichloromethane (MeCN:MeOH:DCM) 75:20:5 v/v/v, containing 0.1% BHT and 0.05% triethylamine (TEA), a solvent modifier and prepared fresh daily. The flow rate was 1.0 ml/min. Solvents for liquid chromatography were of HPLC grade. All solvents for use as the mobile phase in HPLC were filtered through a 0.45 μm cellulose membrane filter and degassed using an ultrasonic bath. β-carotene standard was purchased from Sigma Chemical Company and a concentration 0.2 mg/ml was prepared diluted in the mobile phase and 20 μl injected into HPLC. Peak responses were determined at 450 nm with a variable wavelength programmable photodiode array UV detector (Waters 994) and Waters 520 printer plotter. β-carotene peak was identified by its retention time and compared with that of pure β-carotene standard. Twelve sample extracts were

analyzed. Thin layer chromatography (TLC) and UV–vis absorption spectrophotometry were also used to aid in the identification of β-carotene.

2.2.4. Vitamin A activity

The content of β-carotene obtained was used to calculate the vitamin A activity in the sample. Conventionally, the nutritional significance of carotenoids is related to the pro-vitamin A activity. Vitamin A activity of β-carotene expressed as μg retinol equivalent (RE)/100 g sample was calculated as RE = (μg β-carotene)/6 according to the method described by Tee and Lim (1991).

2.2.5. Analysis of free fatty acid composition

Free fatty acids were obtained by the fatty acids methyl esters (FAMEs) extraction method described by Levy, Maxim and Friedlander (1992) followed by gas chromatography analyses of the total lipid methyl ester from each of the lipid classes. FAMEs samples were analyzed using a Hewlett-Packard (HP) 5890 Series II gas chromatograph (GC) equipped with a fused silica capillary column Omegawax 320 (30 m×0.32 mm, film thickness 0.25 μm) and an FID detector. The GC was connected to an HP integrator model 3396A. The carrier gas was helium. The run method was through a temperature gradient from 110 up to 220°C with an increase rate of 8.0°C/min and a total run time of 40 min. The detector was operated at 260°C. Data were collected and manipulated using a HP integrator. Identification of fatty acids in the samples was performed by comparison with chromatograms of fatty acids standard (C_4–C_{24} fatty acids) from Sigma Chemicals. Usually 80–90% of the peaks in the chromatograms were identified. Fatty acids composition was calculated from the total identified fatty acids area and the values were always the average of at least two to three injections of each duplicate extracts.

2.2.6. Amino acid analysis

Amino acid analysis was performed using the Waters Associates PICO-TAG™ method (Bidlingmeyer, Cohen & Tarvin, 1984), an integrated technique for precolumn derivatisation of amino acids using phenylisothiocyanate (PITC). The PICO-TAG™ techniques comprises of three steps: (i) Hydrolysis of protein or peptide samples to yield free amino acids, (ii) pre-column derivatization of the samples with PITC and (iii) analysis by reverse phase HPLC. The chromatographic separation on the hydrolyzates was performed using a reverse phase Pico-Tag column (3.9×150 mm) C_{18} at 38°C and a UV detector at 254 nm. The solvent system consisted of two eluants: (A) an aqueous buffer and (B) 60% acetonitrile in water. Gradient elution were employed using two pumps programmed to deliver the mobile phases eluants A and B. A gradient which was run for the separation consisted of 10% B traversing to 51% B in 10 min using a convex curve (number 5). A set of amino acid standards (Sigma Chemicals) was analyzed with each set of seven experimental samples. Identification of the amino acids in the samples was carried out by comparison with the retention times of the standards.

According to Block and Mitchell (1946), chemical score concept is the content of essential amino acid in a food as a percentage of the same amino acid in the selected standard hen's whole eggs. The chemical score was calculated by dividing the contents of the essential amino acids in *G. changgi* by the amounts of the same amino acids in whole egg proteins.

2.2.7. Mineral elements

For the determination of mineral elements (calcium, iron, zinc, copper and cadmium), samples were digested by dry ashing and dissolved in 1 M HCl (AOAC, 1990). The final diluted solution for calcium contained 1% lanthanum to overcome interferences. The concentration of the elements in *G. changgi* were determined with atomic absorption spectrophotometry (Perkin–Elmer, model 3110). Triplicate determinations for each element were carried out. The concentration of the elements were determined from calibration curves of the standard elements.

2.2.8. Statistical procedure

For all analyses, the mean and standard deviation for each of the nutrients analyzed were calculated and reported.

3. Results and discussion

3.1. Proximate and biochemical composition

The proximate composition and vitamin C content of *G. changgi* is shown in Table 1. The red algae *G. changgi* was found to contain (wet weight basis): total protein (6.9 ± 0.1)%, crude fiber, (24.7 ± 0.7)%; total lipid, (3.3 ± 0.2)% and ash, (22.7 ± 0.6)%. These values were compared to coresponding data for several local vegetables reported by Tee, Mohd Ismail, Mohd Nasir and Khatijah (1988) and are also included in Table 1. The protein level in *G. changgi* is 6.9%, which is lower than in soyabean, slightly higher than in peas and in broccoli but is much higher than that in the other vegetables. The protein content in most *Gracilaria* species is between 7 and 13% (Briggs & Smith, 1993). The table shows the amount of fiber present in the other vegetables are less than 5.5% and that *G. changgi* has about 5 times higher fiber content than these vegetables. The total lipid content in *G. changgi* is found to be 3.3% which lies in the range for total lipid content for most seaweed, i.e. 1–3% (dry weight) as reported by Chapman

Table 1
Proximate composition and vitamin C content of *G. changgi*[a] and of some vegetables[b]

Foodstuffs	Protein (%)	Total lipids (%)	Fiber (%)	Ash (%)	Vitamin C (mg/100 g)
G. changgi	6.9	3.3	24.7	22.7	28.5
Green bean sprouts	2.6	0.2	0.7	0.3	14.1
Soyabeans, white	33.8	18.9	5.5	4.8	7.5
Peas (green, canned)	3.4	0.4	2.7	1.3	8.1
Red spinach	2.8	0.3	1.5	1.8	48.3
Carrots	1.0	0.1	1.1	0.8	9.5
Broccoli	4.1	0.1	1.0	0.8	85.0
Lettuce	1.2	0.1	0.5	0.7	27.6
Tomato	1.4	0.2	0.5	0.6	25.8
Red pumpkin	0.9	0.1	0.3	0.4	36.5
Cabbage	1.6	0.2	0.9	0.8	53.0
Red chilli	2.8	0.7	4.8	0.9	175.0

[a] Mean values, $n = 3$, wet weight basis.
[b] Source: Tee et al. (1988). Values are based on wet weight.

and Kirst (1979) and Mabeau and Fleurence (1993). Although this value is relatively low, it is still high compared to that of several vegetables reported by Tee et al. (1988) which have less than 1.0% lipid content except for soyabean.

From the recovery experiments for analysis of vitamin C in the samples, the recoveries were in the range of 90–101%, however, no comparison with other method was made. The content of vitamin C in *G. changgi* is 28.5 ± 0.1 mg vitamin C/100 g sample (wet weight) and this value was compared to that in some locally consumed vegetables (Table 1). It was found that vitamin C content in *G. changgi* is comparable to that in lettuce and tomato.

3.2. Beta-carotene content

Fig. 1 shows the HPLC chromatogram of β-carotene in the extracted sample of *G. changgi*. It shows β-carotene peak and also two other peaks which were not identified in our study. The separation and identification of β-carotene was confirmed further with TLC studies of the same extract which gave three separate bands on silica gel TLC plates using a solvent system of hexane/acetone/chloroform/methanol (70:25:10:5, v/v/v/v) indicating presence of three pigments. UV–vis absorption spectra of the pigment spot which has the same R_f value as standard β-carotene was also determined. Therefore, based on the similarity of the behaviour of the peaks separated by HPLC and that by TLC methods and also the absorption spectra obtained for β-carotene from the samples and that of the standard β-carotene, the peak observed in the HPLC chromatogram was identified as β-carotene. From the nutritional point of view, the other two unidentified peaks observed in the HPLC chromatogram are unimportant because they are not precursors of vitamin A.

We determined the stability of β-carotene during sample treatment by measuring the recovery of β-carotene added to the samples. The results showed that the recovery β-carotene was $96\% \pm 1.0$. It was observed that the amount of β-carotene added to the sample should be comparable to the amount expected to be present in the sample to give satisfactory results. Quantitative analysis of β-carotene in 12 dried seaweed sample extracts of *G. changgi* by HPLC method showed that the amount of β-carotene present is 5.2 ± 0.4 mg/100 g sample (dry weight). A comparison study was made on the amount of β-carotene found in *G. changgi* to that present in various locally available vegetables. Tee and Lim (1991) reported amount of β-carotene present in several vegetables were as follows (in mg/100 g): red carrot, 6.8; tapioca shoots, 5.7; mint leaves, 4.8; red spinach, 5.1; Chinese cabbage, 3.0; Chinese mustard leaves, 2.9; swamp cabbage, 1.9; red pumpkin, 0.58; red chillies, 0.47; tomatoes, 0.37 and lettuce, 0.10. This showed that *G. changgi* rank in third after red carrot and tapioca shoots in β-carotene content. β-carotene content in *G. changgi* was comparable to that in mint leaves and red spinach. The other vegetables such as Chinese cabbage, Chinese mustard leaves, swamp cabbage, red pumpkin, red chillies, tomatoes and lettuce have less β-carotene content than *G. changgi*.

The vitamin A activity calculated on the basis of β-carotene content was 865 μg RE/100 g sample. Using the classification of RE values adopted by Tee and Lim (1991), all food items are grouped into four categories; namely, low (< 100 μg RE/100 g edible portion), medium (100–499 μg RE), high (500–599 μg RE) and very high (> 1000 μg RE). The RE value of *G. changgi* would be a higher value if the calculation was based on all the pro-vitamin A carotenoids (i.e. cryptoxanthin, γ- α and β-carotene) content in the sample. Thus *G. changgi* is a potential food source having a high vitamin A activity. The higher content of β-carotene in *G. changgi*

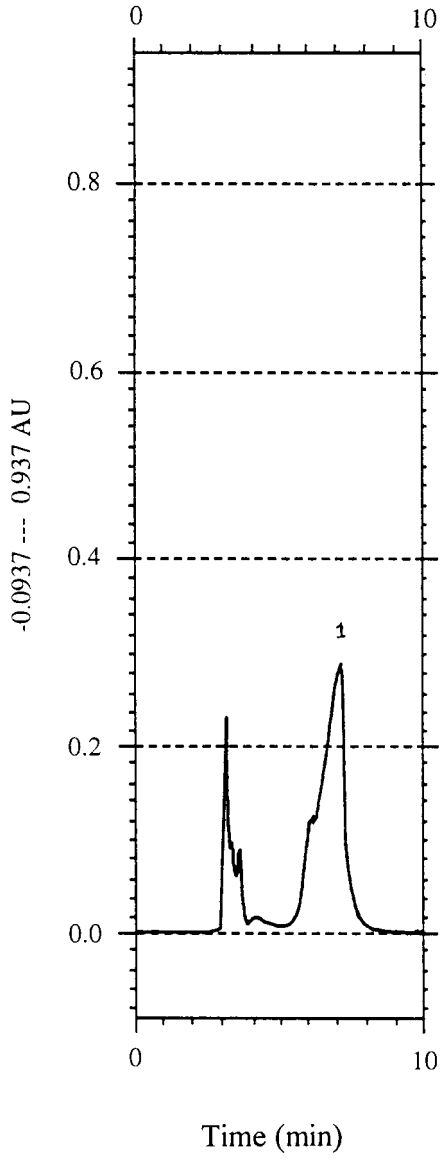

Fig. 1. HPLC chromatogram of β-carotene in *G. changgi* under condotions as given in the text (peak 1, β-carotene).

compared to most of the commonly consumed local vegetables made it a potential source of β-carotene for human consumption.

3.3. Free fatty acid composition

A sample chromatogram of fatty acids composition in *G. changgi* is given in Fig. 2. Gas chromatographic analysis on six sample extracts showed the main free fatty acids present in *G. changgi* are eicosapentaenoic acid, 20:5 ω3 (33.1 ± 6.3%); palmitic acid, 16:0 (22.0 ± 2.7%); oleic acid, 18:1ω9 (21.9 ± 3.4%) and docosahexaenoic acid, 22:6ω3 (12.9 ± 3.3%). *G. changgi* has a higher composition of unsaturated fatty acids (74%), mainly the omega fatty acids, eicosapentaenoic acid and docosahexanoic which are important to human health. The results also showed palmitic acid, 16:0, as the main saturated fatty acid (26%).

3.4. Amino acid composition

Quantitative determination of amino acid concentrations was conducted by HPLC and the amino acid profile is shown in the chromatogram (Fig. 3). Sixteen amino acids were detected and the separation of the amino acids in the samples are reasonably resolved. All of the essential amino acids i.e. methionine, leucine, lysine, cysteine, phenylalanine, tyrosine, arginine, isoleucine, threonine and valine and six non-essential amino acids were found to be present in *G. changgi*. Table 2 shows the amino acid concentration and total nitrogen content in *G. changgi*. The total amino acids in *G. changgi* was 602 μmol amino acid/g sample (dry weight). From this total, 252 μmol amino acid/g sample is made up of essential amino acids. The ratio of essential amino acids to total amino acid is 0.4 i.e. almost half of the amino acid in *G. changgi* consist of essential amino acids. The results also indicated that the ratio of essential amino acids to non-essential amino acids is 0.7. *G. changgi* is rich in glycine, arginine, alanine, glutamic acid, proline, and aspartic acid. Tyrosine and cysteine are present in lower amounts, 9.40 and 4.20 μmol amino acid/g sample compared to the other amino acids. Data on tryptophan are not included in this work since this amino acid is destroyed during acid hydrolysis. The determination of amino acid profile of *G. changgi* is of great value from a nutritional, chemical and biochemical point of view. Many seaweeds have relatively high content of free amino acids which provide seaweed flavors such as glutamic acid which gives a unique flavor and glycine and alanine which give a sweet flavor (McLachlan, Craigie, Chen & Ogetze, 1972).

3.5. Nutritional evaluation

The nutritional value was evaluated by comparing the ratio of the quantity of essential amino acids in *G. changgi* to the respective amino acids based on hen's eggs. Table 3 shows the essential amino acid pattern of *G. changgi* as compared with that of hen's eggs reported by Sikka, Duggal, Singh, Gupta and Joshi (1978). Data in Table 3 are for the concentration of amino acids in g amino acid/16 g nitrogen and were used to calculate the chemical score of the essential amino acids in *G. changgi* according to Meredith and Dull (1979). The food protein quality is valued based on the ten essential amino acids, i.e. arginine, leucine, isoleucine, lysine, methionine, phenylalanine, threonine, tryrosine, cysteine and valine. Since cysteine and tyrosine can replace methionine and phenylalanine, respectively, through metabolic processes, two amino acids are combined, i.e. methionine with cysteine and phenylalanine with tyrosine for

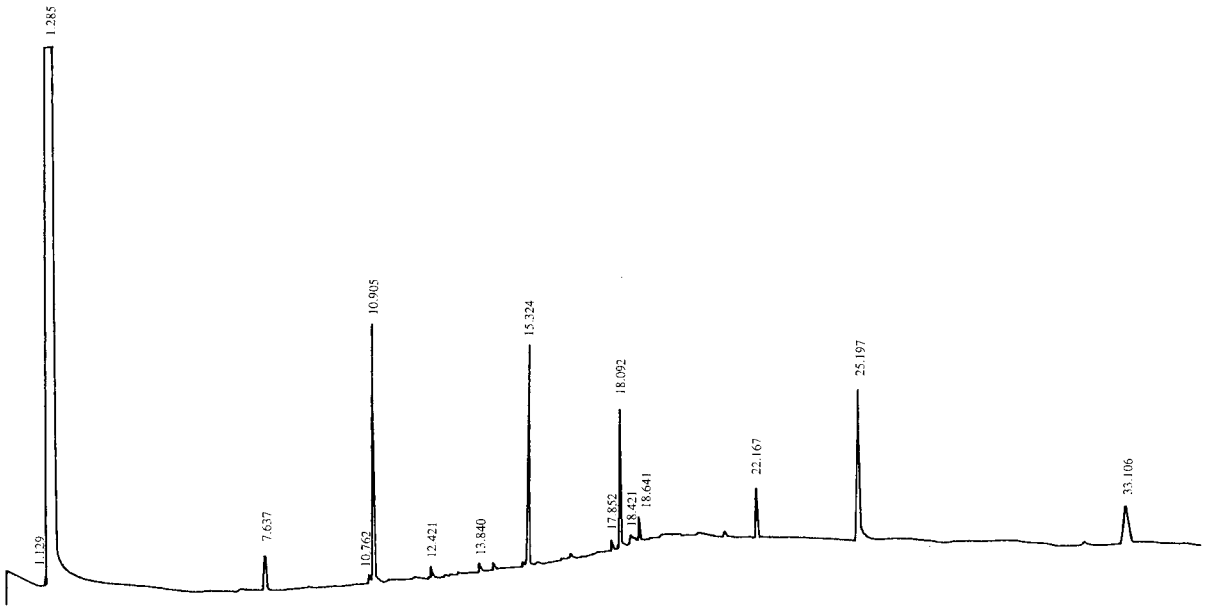

Fig. 2. Fatty acid profile of *G. changgi* (main free fatty acid peaks at retention times: 12.421 min, myristic-acid 14:e; 15.324 min, palmitic acid 16:0; 17.852 min, staric acid 18:0, 18.092 min, oleic acid 18:1ω9; 18.641 min, linoleic acid 18:2ω6; 22.167 min, arachidonic acid 20:4ω6; 25.197 min, eicosapentaenoic acid 20:5ω3; 33.106 min docosahexaenoic acid 22:6ω3).

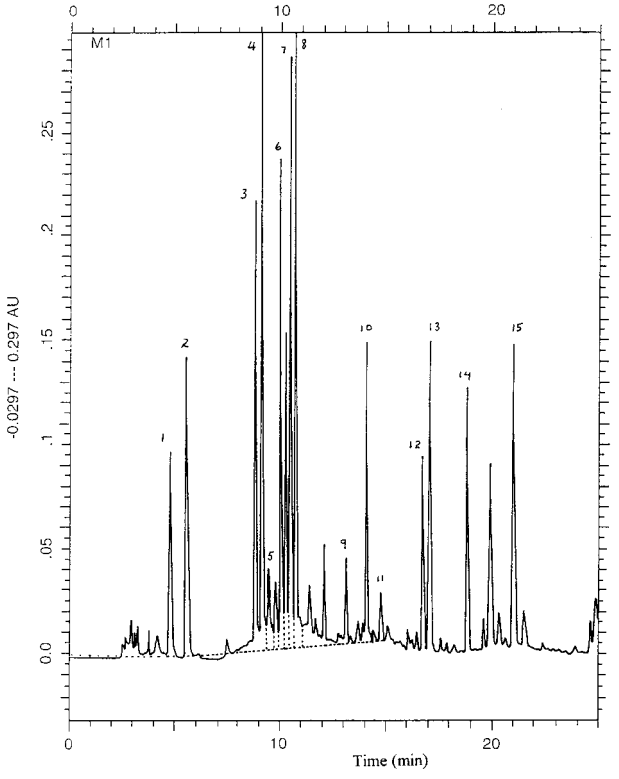

Fig. 3. Amino acid profile of *G. changgi* (peaks: 1, aspartate; 2, glutamate; 3, glycine; 4, histidine; 5, argintine; 6, threonine; 7, alanine; 8, proline; 9, tyrosine; 10, valine, 11, methionine; 12, isoleucine; 13, leucine; 14, phenylalanine; 15, lysine).

Table 2
Amino acid concentration and total nitrogen content in *G. changgi*

Amino acids	Concentration[a] μmol amino acid/g sample (dry weight)
Alanine[a]	65.3 ± 5.2
Valine[b]	31.7 ± 6.4
Leucine[b]	36.5 ± 6.6
Methionine[b]	20.0 ± 8.7
Isoleucine[b]	29.4 ± 6.4
Proline[c]	56.2 ± 8.3
Phenylalanine[b]	29.0 ± 3.6
Glycine[c]	106 ± 10
Threonine[b]	39.8 ± 2.2
Cysteine[b]	4.20 ± 1.2
Tyrosine[b]	9.40 ± 4.9
Aspartic acid[c]	40.1 ± 14
Glutamic acid[c]	63.6 ± 8.7
Lysine[b]	16.6 ± 3.8
Arginine[b]	35.5 ± 4.7
Histidine[c]	19.1 ± 3.9
Tryptophan	ND
Total amino acids	602
EAA[b]	252
Non-EEA[c]	350
Total nitrogen content (g nitrogen/100 g dry weight)	1.10 ± 0.01

[a] Mean of seven determinations ± standard deviation.
[b] EAA, essential amino acids.
[c] Non-EAA, non essential amino acids. ND, not determined.

Table 3
Chemical score of the essential amino acids in *G. changgi*

Essential amino acids	Amino acid concentration in g of amino acid/16 g of nitrogen		Chemical score (%) (egg ratio×100)
	G. changgi	Hen's eggs[a]	
Isoleucine	5.7	5.8	98
Leucine	7.0	8.9	78
Lysine	3.5	6.7	53
Phenylalanine + tyrosine	9.5	10.3	92
Methionine + cysteine	5.8	5.4	108
Threonine	6.9	5.1	134
Valine	5.4	7.5	72
Arginine	9.0	6.2	146

[a] Source: Sikka et al. (1978).

the calculation of chemical score (Sikka et al.). Table 3 shows that lysine has a low chemical score value i.e. 53% and thus it seemed to be the limiting essential amino acid in *G. changgi*. Almost all of the essential amino acids studied in *G. changgi* have a high chemical score value which implied that essential amino acids present in this seaweed have a high biological protein value.

3.6. Mineral contents

The mineral contents of *G. changgi* (Table 4) in mg/100 g sample (dry weight) are: Ca, 651 ± 5.2; Fe, 95.6 ± 3.7; Zn, 13.8 ± 4.1; Cu, 0.8 ± 0.1 and Cd, 0.30 ± 0.1. The results show that *G. changgi* is rich in Ca with moderate amounts of Fe whereas Zn, Cu and Cd are present in small quantities. The amount of Ca and Fe present in *G. changgi* were compared to data for other vegetables reported by Tee et al. (1988) as given in Table 4. There was no data reported for elements Zn, Cu and Cd in these vegetables but *G. changgi* contain high amounts of Ca and Fe relative to these vegetables which is due to its metabolic system in which it is capable of directly absorbing elements from the seawater.

Table 4
Concentration of elements (mg/100 g wet weight) present in *G. changgi*[a] and in some vegetables[b]

Foodstuffs	Ca	Fe
G. changgi	651	95.6
Green bean sprouts	25.0	1.7
Soya beans, white	200	6.0
Peas	25.0	1.9
Red spinach	120	4.0
Carrots	140	0.8
Broccoli	40.0	0.7
Lettuce	50.0	1.5
Tomato	12.0	0.8
Red pumpkin	21.0	0.7
Cabbage	40.0	0.6
Red chilli	15.0	1.8

[a] Mean, $n = 3$.
[b] Source: Tee et al. (1988).

4. Conclusions

The edible seaweed *G. changgi*, a red algae found in Malaysia was analyzed for its biochemical and mineral composition. Its nutritional composition was then compared to that in several other local vegetables. It was found to contain a higher concentration of fiber and mineral and has a moderate concentration of lipid and protein. These comparison studies of *G. changgi* with other foods show its potential of being a good source for β-carotene, minerals and fibre. It is also rich in omega fatty acid with relatively high levels of eicosapentaenoic acid (20:5ω3) which is regarded as beneficial to health. It is also a good source of essential amino acids. In contrast, most vegetables showed absence of certain essential amino acids while omega fatty acids are rarely found in plant foods. Thus results of the present study conclude that *G. changgi* is a potential health food in human diets and may be of use to the food industry as a source of ingredients with high nutritional value. *G. changgi* can provide a dietary alternative due to its nutritional value and its commercial value can be enhanced by improving the quality and expanding the range of seaweed-based products.

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