

Nutritional Composition of Macroalgae in Tanjung Tuan, Port Dickson, Malaysia

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ABSTRACT There are diverse species of macroalgae in Tanjung Tuan, Port Dickson that include the division of Phaeophyta such as *Padina gymnospora* (Kützinger) Vikcers, *Sargassum baccularia* C. Agardh, *Sargassum binderi* Sonder, and *Turbinaria conoides* (J. Agardh) Kützinger together with the division of Chlorophyta such as *Caulerpa lentillifera* J. Agardh and *Caulerpa racemosa* (Forsskal) J. Agardh. Nutritional compositions of samples collected were determined. Content analysis of moisture, ash, protein, carbohydrate, crude fiber, fat content, vitamins (vitamin A, vitamin B₁, vitamin B₂, vitamin C, Niacin) and minerals (phosphorus, sodium, potassium, calcium, iron, magnesium, copper and zinc) of the selected macroalgae had been carried out using standard methods. Comparisons with corresponding nutrient values in several commonly consumed local vegetables (spinach), local macroalgae e.g. *Gracillaria changii* and macroalgae or macroalgae derived-products from other countries e.g. Dulse, Irish Moss, Kombu, Nori, Wakame, seaweed agar (raw) were done. *Turbinaria conoides* showed the overall best reading compared to five other species because it showed higher contents of ash (4.7 %), vitamin A (24.1 mg/kg, 80333 IU), niacin (274 mg/kg), sodium (13085 mg/kg), potassium (21137 mg/kg), calcium (2353 mg/kg), magnesium (4026 mg/kg), copper (25.2 mg/kg) and zinc (49.1 mg/kg).

ABSTRAK Terdapat pelbagai spesies makroalga di Tanjung Tuan, Port Dickson yang terdiri daripada divisi Phaeophyta seperti *Padina gymnospora* (Kützinger) Vikcers, *Sargassum baccularia* C. Agardh, *Sargassum binderi* Sonder, dan *Turbinaria conoides* (J. Agardh) Kützinger bersama dengan divisi Chlorophyta seperti *Caulerpa lentillifera* J. Agardh dan *Caulerpa racemosa* (Forsskal) J. Agardh. Komposisi nutrien daripada sampel yang diperolehi telah dikenalpasti. Analisis seperti kelembapan, abu, protein, karbohidrat, serat, kandungan lemak, vitamin-vitamin (vitamin A, vitamin B₁, vitamin B₂, vitamin C, niasin) dan mineral-mineral (fosforus, sodium, potassium, kalsium, zat besi, magnesium, kuprum, dan zink) yang terdapat dalam makroalga yang terpilih telah dikenalpasti menggunakan kaedah-kaedah tertentu. Perbandingan dengan kandungan nutrien yang terdapat di dalam sayuran tempatan yang biasa dimakan seperti bayam, makroalga tempatan seperti *Gracillaria changii* dan makroalga atau produk berasaskan makroalga dari negara luar seperti Dulse, Irish Moss, Kombu, Nori, Wakame, agar rumput laut telah dilakukan. *Turbinaria conoides* telah menunjukkan bacaan keseluruhan yang terbaik berbanding dengan lima spesies yang lain kerana ia telah menunjukkan kandungan nutrien yang lebih tinggi pada abu (4.7 %), vitamin A (24.1 mg/kg, 80333 IU), niasin (274 mg/kg), sodium (13085 mg/kg), potassium (21137 mg/kg), kalsium (2353 mg/kg), magnesium (4026 mg/kg), kuprum (25.2 mg/kg) dan zink (49.1 mg/kg).

(Nutritional composition; Macroalgae)

INTRODUCTION

Algae are a "group of plant" that dominates the aquatic environment [1]. The "macroalgae",

usually referred to as seaweed, have been commercially cultured for over 300 years [2]. Most people in the United States ingest red or brown algae products everyday in chocolate milk,

toothpaste, candy, cosmetics, ice creams, salad dressing and many other household and industrial products [3].

In Malaysia, the macroalgae (seaweed) has not been exploited widely as Malaysians had not been aware of its importance as a food product such in Japan and China. Only those inhabiting nearby islands and along beaches have been using seaweeds as fertilizer for farming while a minority uses it as food supply. Seaweed as a food in Malaysia is not as common as it is 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 [4].

Macroalgae are found in the sea and could be viewed clearly during the low tide. Most of the macroalgae are macroscopic in size and belong to the division of Phaeophyta (brown algae), Rhodophyta (red algae) and a number of microscopic forms from the division of Cyanobacteria (blue-green algae) [5]. Chlorophyta are commonly used as food due to high content of vitamins and minerals. Phaeophyta are typical suppliers of alginic acid. Rhodophyta are responsible to produce agar-agar and carrageenan.

Macroalgae are rich in protein, carbohydrates, amino acids, trace elements and vitamins [6]. As a result of recent interests in simple living, the potentials of macroalgae as a source of natural and healthy food became widely recognized and studies on the nutritional values of macroalgae have become more widespread [7]. In comparison with land vegetables, macroalgae are potentially good sources of polysaccharides, minerals and certain vitamins [8].

Reports on certain edible seaweed showed that many contain significant amounts of protein, vitamins and mineral essential for human nutrition [9, 10, 11]. 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, gelatinous dishes or concoctions. The nutrient composition of seaweed varies and

is affected by species, geographic area, and season of the year and temperature of water. These sea-vegetables are of nutritional interest as they are low calorie food, but rich in vitamins, minerals and dietary fibers [12].

MATERIAL AND METHODS

Collection of samples

Collection of macroalgae was done along the shore line of Tanjung Tuan, Port Dickson, located on the west coast of Malaysia during the low tide. The macroalgae were stored in plastic bag filled up with sea water to avoid from dryness. The samples then were washed in running water and freeze dried. For most of the analysis, dried samples were used except for analysis of moisture where fresh samples were used.

Analytical methods

Analysis such as carbohydrate, crude fiber and fat content were determined by using standard methods. Air oven method had been used to analyze moisture content, and Soxhlet Method to determine fat content of the sample. Protein content was determined by the micro-Kjeldahl method [13].

Vitamins determination

Some of the vitamins (vitamin A, B₁, B₂, C and Niacin) of the macroalgae were also examined. Vitamin A was determined by High-pressure liquid Chromatography method. Indophenol dye method had been used to analyze vitamin C [13].

Mineral elements

For determination of mineral elements (phosphorus, sodium, potassium, calcium, iron, magnesium, copper and zinc), samples were digested by dry ashing and dissolved in 1 M HCL. The concentrations of the elements in samples were determined with atomic absorption spectrophotometry [14].

Statistical procedure

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

RESULTS AND DISCUSSION

There are a diverse species of macroalgae in Tanjung Tuan, Port Dickson that include the division of Phaeophyta such as *Padina gymnospora*, *Sargassum baccularia*, *Sargassum*

binderi, and *Turbinaria conoides* together with the division of Chlorophyta such as *Caulerpa lentillifera* and *Caulerpa racemosa*.

The nutrient composition, vitamins and minerals contents of macroalgae are shown in Table 1, 2 and 3. These values were compared to corresponding data for several local vegetables (spinach) reported by USDA [15] which were also included in Table 1, 2 and 3. Spinach was chosen because it is consumed on a daily basis. We also compared the nutritional composition in six types of macroalgae found in Port Dickson with *Gracillaria changii* (found in Malaysia), macroalgae and products of macroalgae from other countries (Table 1, 2 and 3) e.g. Dulse (*Palmaria palmata*), Irish Moss (*Chondrus crispus*), Kombu (*Laminaria japonica*), Nori (*Porphyra* sp.), Wakame (*Undaria pinnatifida*) and seaweed agar (raw).

From the result, macroalgae showed higher content of nutrient compared to vegetables (spinach). *Turbinaria conoides* showed the overall best reading compared to another five selected species of macroalgae found along the shore of Tanjung Tuan, Port Dickson. It showed higher contents of ash (4.7%), vitamin A (24.1 mg/kg or 80333 IU), niacin (274 mg/kg), sodium (13085 mg/kg), potassium (21137 mg/kg), calcium (2353 mg/kg), magnesium (4026 mg/kg), copper (25.2 mg/kg) and zinc (49.1 mg/kg). Algae supplement is not recommended during pregnancy, as the mineral demand for pregnant women is different from normal requirements. It is therefore, not suggested for infants too. The discussion of macroalgae intake will be emphasized in allowance intake for adolescents and adults adapted from Recommended Dietary Allowance, National Research Council [16].

Vitamins are essential to the human body. Vitamins help the body turn food into energy and tissues. Vitamin A prevents night blindness and other eye problems, as well as some skin disorders, such as acne. Vitamin A acts as an antioxidant, helping to protect the cells against cancer and other diseases and is necessary for new cell growth. This important vitamin also slows the aging process. Protein cannot be utilized by the body without vitamin A. *Turbinaria conoides* showed highest content of vitamin A compared to other macroalgae and spinach with the value of 24.1 mg/kg or 80333 IU. Dried dulse contains the highest content of

vitamin A with the value of 8010 IU or 2.403 mg/kg compared to another product of macroalgae. Nori also showed high content of vitamin A with the value of 5202 IU or 1.56 mg/kg (Table 1). Single dose of vitamin A up to 300 mg (300,000 RE or 1 million IU) administered to adults have resulted in only transient toxic signs [17]. The recommended intakes of vitamin A for adolescent and adult are similar, which is 1000 µg RE per day for males and 800 µg per day for females [18, 19]

Vitamin B₁ (thiamine) enhances circulation and assists in blood formation, carbohydrate metabolism and the production of hydrochloric acid, which is important for proper digestion. Thiamine also optimizes cognitive activity and brain function. *Caulerpa racemosa* and *Caulerpa lentillifera* showed higher content of vitamin B₁ compared to other macroalgae and spinach with the value of 8.9 mg/kg and 8.8 mg/kg. The highest value of thiamine content in outside macroalgae is in dried dulse with the value of 1.6 mg/kg (Table 1). The recommended daily allowance for both females and males intake are in the range of 0.9 - 1.5 mg [16].

Vitamin B₂ (riboflavin) is necessary for red blood cell formation, antibody production, cell respiration and growth. For vitamin B₂, *Sargassum binderi* and *Sargassum baccularia* showed highest content of vitamin B₂ compared to other macroalgae and spinach which is 4.7mg/kg and 4.5 mg/kg. Irish moss and Nori also has a high content of vitamin B₂ with the value of 4.66 mg/kg and 4.46 mg/kg (Table 1). The recommended daily intakes are in the range of 0.9 - 1.7 mg [16].

Vitamin C (ascorbic acid) is an antioxidant that is required for tissue growth and repair, adrenal gland function, and healthy gums. Because the human body cannot manufacture vitamin C, it must be obtained through the diet or in the form of supplements. Nori contains consist the highest content of vitamin C compared to other macroalgae and product of macroalgae with the value of 390 mg/kg. Spinach also has a high content of vitamin C with the value 281 mg/kg. *Caulerpa lentillifera* contents higher vitamin C which is 274 mg/kg compared to macroalgae in Port Dickson (Table 1). The recommended intake for both women and men are in the range of 50 - 60 mg [16].

Table 1. Analysis of vitamin contents (mg/kg) in six types of macroalgae found in Port Dickson, spinach^a, *Gracillaria changii*^b, macroalgae from another country^c (Dulse dried, Irish Moss, Kombu, Nori and Wakame) and seaweed agar, raw^d

SPECIES	VITAMIN A	VITAMIN B ₁ (THIAMINE)	VITAMIN B ₂ (RIBOFLAVIN)	VITAMIN C	NIACIN
<i>Sargassum baccularia</i>	15.2	8.3	4.5	224	98
<i>Sargassum binderi</i>	20.1	6.3	4.7	254	115
<i>Caulerpa lentillifera</i>	15.3	8.8	2.5	274	88
<i>Caulerpa racemosa</i>	18.6	8.9	3.2	225	90
<i>Turbinaria conoides</i>	24.1	5.2	4.3	112	274
<i>Padina gymnospora</i>	17.5	8.4	3.6	85	198
Spinach	2014.5 IU	0.77	1.9	281	7.23
<i>Gracillaria changii</i>	NA	NA	NA	285	NA
Dulse, dried	8010 IU	1.6	1.1	120	32000
Irish Moss	NA	0.15	4.66	NA	5.93
Kombu	1161 IU	0.5	1.5	NA	4.7
Nori	5202 IU	0.98	4.46	390	14.7
Wakame	3601 IU	0.6	2.3	30	16
Seaweed agar, raw	NA	0.05	0.22	NA	0.55

^a Source : Spinach - Nutrient Information [15]

^b Source : Proximate composition and vitamin C content of *G. changii* and some vegetable [4]

^c Source : Table Nutritional value of Sea Vegetables [29]

^d Source : Nutrition information : seaweed (agar, raw) [30]

Table 2. Nutrients analysis composition of six types of macroalgae found in Port Dickson, spinach^a, *Gracillaria changii*^b, macroalgae from another country^c (Dulse dried, Irish Moss, Kombu, Nori and Wakame) and seaweed agar, raw^d

SPECIES	MOISTURE	ASH	PROTEIN	CARBOHYDRATE	CRUDE FIBER	FAT CONTENT
<i>Sargassum baccularia</i>	87.1 %	3.6 %	7.7 %	79.7 %	8.7 %	0.3 %
<i>Sargassum binderi</i>	87.1 %	3.9 %	8.9 %	78.0 %	8.9 %	0.3 %
<i>Caulerpa lentillifera</i>	92.3 %	2.1 %	15.9 %	72.9 %	8.4 %	0.7 %
<i>Caulerpa racemosa</i>	95.8 %	1.6 %	12.7 %	76.9 %	8.0 %	0.8 %
<i>Turbinaria conoides</i>	84.3 %	4.7 %	6.5 %	79.7 %	7.9 %	1.2 %
<i>Padina gymnospora</i>	90 %	4.7 %	9.8 %	76.8 %	8.4 %	0.3 %
Spinach	91.58 %	1.72 %	2.86 %	3.5 %	2.7 %	0.35 %
<i>Gracillaria changii</i>	NA	22.7 %	6.9 %	NA	24.7 %	3.3 %
Dulse, dried	NA	NA	13.3 %	NA	NA	NA
Irish Moss	NA	NA	1.51 %	NA	NA	0.16 %
Kombu	NA	NA	1.68 %	NA	1.33 %	0.56 %
Nori	NA	NA	5.81 %	NA	0.27 %	0.28 %
Wakame	NA	NA	3.03 %	NA	0.054 %	0.064 %
Seaweed agar, raw	91.32 %	1.36 %	0.54 %	6.75 %	0.5 %	0.03 %

^a Source : Spinach - Nutrient Information [15]

^b Source : Proximate composition and vitamin C content of *G. changii* and some vegetable [4]

^c Source : Table Nutritional value of Sea Vegetables [29]

^d Source : Nutrition information : seaweed (agar, raw) [30]

Dickson,
Nori
NIACIN
98
115
88
90
274
198
7.23
NA
32000
5.93
4.7
14.7
16
0.55
FAT
CONTENT
0.3 %
0.3 %
0.7 %
0.8 %
1.2 %
0.3 %
0.35 %
3.3 %
NA
0.16 %
0.56 %
0.28 %
0.64 %
0.03 %

Table 3. Analysis of minerals contents (mg/kg) in six types of macroalgae found in Port Dickson, *Sargassum*, macroalgae from another country^b (Dulse dried, Irish Moss, Kombu, Nori and Wakame) and seaweed agar, raw^c

SPECIES	P	Na	K	Ca	Fe	Mg	Cu	Zn
<i>Sargassum baccularia</i>	11.0	726	540	653	834	2463	0.5	15.5
<i>Sargassum binderi</i>	17.4	753	848	739	563	2788	2.3	18.9
<i>Chilodactylus lentillifera</i>	25.4	12297	1413	32.7	145	170	3.0	6.2
<i>Chilodactylus racemosa</i>	61.8	11734	2572	106	723	1865	2.1	13.2
<i>Turbinaria conoides</i>	58.6	13085	21137	2353	42.0	4026	25.2	49.1
<i>Padina gymnospora</i>	64.4	172	671	538	2.7	1311	19.5	5.6
Spinach	490	790	5580	990	27.1	790	1.3	5.3
Dulse, dried	3860	99170	22700	6320	792	5930	NA	39
Irish Moss	1570	670	630	720	89	NA	1.49	19.5
Kombu	420	2330	890	1680	28.5	1210	1.3	12.3
Nori	580	480	3560	700	18	20	2.64	10.5
Wakame	800	8720	500	1500	21.8	1070	2.84	3.8
Seaweed agar, raw	50	90	2260	540	18.6	670	0.61	5.8

^a Source : Spinach - Nutrient Information [15]
^b Source : Table Nutritional value of Sea Vegetables [29]
^c Source : Nutrition information : seaweed (agar, raw) [30]

Usual daily dietary intake of vitamin C (25 to 75 mg) can enhance the intestinal absorption of dietary non-heme iron by two to fourfold [20, 21]. Pauling had been reported the daily intakes of ascorbic acid of 1g or more can help to reduce the frequency and severity of symptoms of the common cold and other respiratory illness [22]. The minimum intakes of vitamin C is ranging from 6.5 to 10 mg/day were required [23, 24].

Vitamin B₃ (Niacin) is needed for proper circulation and healthy skin. It aids in the functioning of the nervous system, in the metabolism of carbohydrates, fats, proteins, and in the production of hydrochloric acid for the digestive system. Dried dulse contains the highest content of niacin with the value of 32000 mg/kg compared to other macroalgae and product of macroalgae. *Turbinaria conoides* also has a high content of vitamin B₃, which is 274 mg/kg compared to another macroalgae and spinach (Table 1). The recommended daily allowance are in the range of 13 - 20 mg NE per day, which mean the minimum intake should be taken per person in order to avoid deficiency [16].

Caulerpa racemosa and *Caulerpa lentillifera* showed highest contents of moisture compared to other macroalgae and spinach with the value 95.8% and 92.3%. Seaweed agar (raw) also has a high content of moisture with the value of 91.32% (Table 2).

Gracillaria changii contains the highest content of ash compared to other macroalgae with the value of 22.7%. *Turbinaria conoides* and *Padina gymnospora* also has a high content of ash with the value of 4.7 % (Table 2).

Protein is essential for growth and development. It provides the body with energy, and is needed for the manufacture of hormones, antibodies, enzymes and tissues. It also helps maintain the proper acid-alkali balance in the body. Protein provides energy at 4 calories per gram, but it is more important as the body's building material. *Caulerpa lentillifera* showed higher contents of protein compared to other macroalgae and spinach with the value of 15.9%. Dried dulse consist 13.3% of protein content higher than other product of macroalgae outside (Table 2). The recommended range of daily intake is 45 - 63 g/day [16].

Carbohydrates supply the body with the energy it needs to function. Carbohydrate is the main source of blood glucose, which is a major fuel for all of the body's cells and the only source of energy for the brain and red blood cells. *Sargassum baccularia* and *Turbinaria conoides* showed higher contents of carbohydrate compared to other macroalgae and spinach with the value of 79.7% (Table 2). One gram of carbohydrate yields 4 kcal. Thus, for people consuming as little as 2000 kcal/day, the recommended intake would be at least 250g [16]. Seaweed agars (raw) consist of 6.75% of

carbohydrate lower than fresh macroalgae found in Port Dickson.

Dietary fiber is the part of a plant that is resistant to the body's digestive enzymes. A high-fiber diet reduces the risk of colon cancer, perhaps by speeding the rate at which stool passes through the intestine and by keeping the digestive tract clean. *Gracillaria changii* contains the highest content of crude fibre with the value of 24.7% compare to other macroalgae and products of macroalgae outside. *Sargassum binderi* and *Sargassum baccularia* showed higher contents of fiber compared to other macroalgae in Port Dickson and spinach with the value of 8.9% and 8.7% (Table 2).

Fats makes skin and body oils, regulates your body by forming hormones, insulates and pads internal organs, carries fat-soluble vitamins throughout the body, helps repair damaged tissue and fight infections, and provides a source of energy. Fats are the way our body stores up energy. Fats pack a lot of energy. Each gram of fat provides 9 calories. *Gracillaria changii* consist highest content of fat content with the value 3.3 % compare to other macroalgae and products of macroalgae. *Turbinaria conoides* showed higher contents of fat compare to another macroalgae and spinach with the value of 1.2 % (Table 2). Kombu showed 0.56 % of fat content higher than another product of macroalgae outside.

Dried dulse contains the highest content of phosphorus with the value of 3860 mg/kg compare to other macroalgae. *Padina gymnospora* consist much higher content of phosphorus compare to other macroalgae and spinach which is 64.4 mg/kg (Table 3). The recommended allowance is 800 mg/day for children 1 to 10 years, 1200 mg/day for ages beyond 24.

Dried dulse contains the highest content of sodium with the value of 99170 mg/kg compared to other macroalgae. *Turbinaria conoides* consists of much higher content of sodium compared to other macroalgae in Port Dickson and spinach which is 13085 mg/kg (Table 3). Amount of 2400 mg daily is needed.

Dried dulse contains the highest content of potassium with the value of 22700 mg/kg compared to other macroalgae. *Turbinaria*

conoides contains the highest sum of potassium, 21137 mg/kg among six examined macroalgae in Port Dickson and spinach (Table 3). Potassium is well absorbed, but is not stored in large quantities in the body.

Dried dulse contains the highest content of calcium with the value of 6320 mg/kg compare to other macroalgae. *Turbinaria conoides* contains the highest sum of calcium, 2353 mg/kg among six examined macroalgae and spinach (Table 3). It is sufficient when compared to the recommended allowance, which is 1200 mg/day for both sex groups from ages 11-24 years. For elder age groups, the previous allowance of 800 mg/day is retained [16].

Sargassum baccularia contains the highest sum of iron content compared to other examined species of macroalgae and spinach. The total amount of iron in *Sargassum baccularia* is 834 mg/kg. Dulse dried has a higher content of iron with the value of 792 mg/kg (Table 3). The recommended range is in 10 - 15 mg/day. Females and adolescents require higher iron demand compared to males and adults. Person who has eaten little or no animal protein (vegetarians) may require higher amount of food iron [25]. The high figure of iron in *Padina gymnospora* could be toxic for some people who are genetically at risk from iron overload [26, 27]. Other than that, it will not lead to excessive toxicity.

Dried dulse contains the highest content of magnesium with the value of 5930 mg/kg compared to other macroalgae. *Turbinaria conoides* content much higher of magnesium with the amount of 4026 mg/kg compared to other macroalgae in Port Dickson and spinach (Table 3). The recommended range of intake is 240 - 400 mg/day [16]. Seelig had concluded that an intake of 6 mg/kg per day is needed to ensure adequate magnesium status [28].

Turbinaria conoides contains the highest amount of copper, 25.2 mg/kg compared to other macroalgae and product of macroalgae (Table 3). The amount of copper needed to meet normal daily recommended intakes will be different for different individuals. The average recommended dosage for adult and adolescent males is 1.5 - 2.5 mg per day; adult and adolescent females is 1.5 - 3.0 mg per day.

Turbinaria conoides has a higher zinc content that is 49.1 mg/kg compared to other macroalgae and spinach (Table 3). The recommended allowance for male is 15 mg/day while, for women is 12 mg/day [16].

CONCLUSIONS

Overall view illustrates that macroalgae consist of better concentration of biominerals compared to vegetables (spinach). From the results of the present study, it is concluded that macroalgae 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. Macroalgae can provide a dietary alternative due to its nutritional values and its commercial value can be enhanced by improving the quality and expanding the range of seaweed-based products. The measured quantity of biominerals and biovitamins in macroalgae are still far from the value of excessive toxicity that suggested by USRDA. Therefore, macroalgae as source of pharmaceutical could be exploited in order to enhance and to improve the minerals contents for maintaining good health of humans. Advance research may perhaps be done in order to discover more benefits of these algae.

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