
***Chara corallina* Klein ex C. L. Willdenow, the first report of an edible freshwater alga in Thailand and its potential for food**

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Abstract The findings revealed that local knowledge is transmitted primarily through observation and experiential learning. Such knowledge enables community members to identify natural sources of KamKung alga or Sai Don (*Chara corallina*, *Cc*), apply practical methods for algal identification, distinguish between edible and inedible species, and utilize the alga for food. The *Cc* was determined to be a good source of protein (19.55±0.33 g/100g dw) and minerals (10.64 g/100g dw), with several amino acids, particularly methionine, identified in the algal sample. Similar to other algae, *Cc* had low lipid content (2.54 g/100g dw) with dominant palmitic acid (50.89% of total fatty acids). Polyunsaturated fatty acid was the main component of essential fatty acids including linoleic acid (23.34%) and α -linolenic acid (6.38%). One gram of dried *Cc* intake was equivalent to 9.98 kJ. High calcium content and high ratio of K/Na at 29.56:1 were recorded. Antioxidant substances including ascorbic acid and selenium were also present. Cobalamin, which is rarely available in higher plants, was also presented in this species. In addition, the aqueous extract of *Cc* composed of HCl/EtOH and indomethacin exhibited gastroprotective activity in a rat model of water immersion-restraint stress-induced gastric ulcers. Based on the results of this study, *Cc* is of considerable interest as a potential food source. Therefore, this study is provided the first comprehensive evaluation of edible *C. corallina*, focusing on its nutritional value, gastroprotective activity, and molecular identification.

Keywords: Charophytes, Edible algae, Gastroprotective, Thailand, Food

Introduction

Algae are used as a nutritional functional food source for human being since ancient times. Freshwater algae benefit humans as a food and also have

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agricultural, environmental science and medicinal functions. Today, algal production is highly important with wide-ranging applications. However, uses of freshwater algae have not been fully developed due to the lack of basic knowledge, limited species and diverse data. In Thailand, freshwater macroalgae grow in water bodies as one of the most important natural resources, especially in terms of consumption. Local people have utilized varieties of edible freshwater macroalgae as medical ingredients by inheriting knowledge passed down from previous generations. *Nostochopsis* spp. exhibited nutraceutical potential, anti-gastric ulcer activity and anti-inflammatory and antioxidant activity (Peerapornpisal *et al.*, 2006). Some local people consume *Cladophora* and *Microspora* to ameliorate the symptoms of stomach ulcers (Thiamdao *et al.*, 2012).

Charophytes are submerged water plants that grow in fresh, brackish and saline water throughout the world. They are distinguished from other aquatic macrophytes on the basis of their overall simple morphology and distinctive oospore pattern (Casanova and Karol, 2014). Characean algae are also called stoneworts or brittleworts due to extensive extracellular calcification (Singh *et al.*, 2013). The presence of Characeae is often associated with clean and rather hard water with low phosphorus concentration (Singh *et al.*, 2013). The Characeae show diversity in aquatic habitats and can be found in coastal lagoons, lakes, ditches, streams, bog pools, flushes, puddles, concrete tanks, reservoirs and excavations. Most species prefer fast-flowing water, with a few found in slow-moving streams and canals (Schubert and Blindow, 2003). Various species of *Chara* in North America colonize oligotrophic lakes down to depths of 30 m. (Wehr and Sheath, 2003). *Chara* is a genus of gray-green branched multicellular algae that is often confused with submerged flowering plants. A total of 37 species of *Chara* has been recorded (John *et al.*, 2002), with *C. hispida* and *C. gmnnohylla* used as bioindicators of aquatic environments (Barinova *et al.*, 2014). A methanolic extract of *C. contraria* showed strong antifungal and antitumor activity, while nonpolar extracts of *C. globularis* showed moderate antibacterial activity (Bankova *et al.*, 2001; Ghazala *et al.*, 2004). Several species of *Chara* have been reported in Thailand, with 9 species documented by Chanyarak (1977) and 6 species subsequently recorded in the central region by Sitwipusiri (2015). Although *Cc* is widely distributed in freshwater ecosystems, its consumption by humans has not been previously documented. Consumption of *Cc* has been documented only in local communities in Krabi Province, southern Thailand, where it is traditionally known as "Kam Kung" or "Sai Don. Despite its local use as an edible aquatic plant, information regarding its nutritional composition, health-promoting properties, and taxonomic identity is limited. Accordingly, the study aimed to comprehensively characterize edible *C. corallina* by evaluating its nutritional composition, gastroprotective activity, and molecular identification, thereby providing scientific evidence for its potential food applications.

Materials and methods

Local knowledge study

This study was conducted in five districts of Krabi Province (Nuea Khlong, Khlong Thom, Lam Thap, Khao Phanom and Plai Phraya), where *Cc* is traditionally consumed. The study investigated local knowledge regarding *Cc*, including its occurrence, harvesting practices, utilization, and conservation, from June 2018 to July 2019. Data were collected through field surveys, participatory observations during algal harvesting and species identification, and structured in-depth interviews with key informants possessing extensive traditional knowledge of the species. Interviews were conducted in local communities and markets across the five districts to document the traditional consumption and use of *Cc*.

Investigation and preparation of the algal material

Cc samples were collected during the rainy season (June 2018-July 2019) from natural ponds in Nuea Khlong District, Krabi Province, Thailand. Additional samples were purchased from local markets in Khlong Thom and Nuea Khlong districts, Thailand. Fresh samples were washed thoroughly using freshwater to remove epiphytes on the surface before air-drying and storage in plastic zip packages until required for further analysis.

Species identification using morphological and molecular data

Cc specimens were identified using both morphological and molecular approaches. For morphological identification, specimens were immersed in clean water and examined using relevant publications and books including www.algaebase.org (Borges and Necchi, 2017; John *et al.*, 2002; Schubert and Blindow, 2003). For molecular identification, total DNA was extracted from dried apical portions of two algal specimens (C1 and C2) using a QIAGEN DNeasy Plant Mini Kit. The ribulose-bisphosphate carboxylase (*rbcL*) gene was amplified following Kato *et al.*, (2008), as this marker is effective for *Chara* phylogenetics. Amplified products were commercially sequenced (U2Bio Inc., Seoul, South Korea). Sequences were edited, assembled, and aligned in Geneious Prime (Biomatters, <http://www.geneious.com/>). Phylogenetic trees were reconstructed using maximum-likelihood (ML) in IQ-TREE (Rambaut *et al.*, 2018) and Bayesian inference (BI) in MrBayes v3.2 (Ronquist *et al.*, 2012). ML analyses used the GTR+R model with 1000 bootstrap replicates via the IQ-TREE web server (<http://iqtree.cibiv.univie.ac.at>). BI analyses employed a GTR+I+R model with two parallel runs of four Markov chains for one million generations,

sampling every 1000 generations with a 25% burn-in. Trees were visualized using FigTree v1.4.3 (Trifinopoulos *et al.*, 2016).

Nutrition evaluation

Proximate compositions including moisture, protein, lipid, fiber and ash contents were determined according to the AOAC procedure (AOAC, 2012). Carbohydrate was calculated following the compendium of methods for food analysis (Department of Medical Sciences and National Bureau of Agricultural Commodity and Food Standards, 2003). Dried sample powder was prepared and analyzed for amino acid composition by an in-house method based on AOAC, (1989), while levels of ten minerals were measured by in-house methods based on AOAC, (2012). For the fatty acid profile, total lipid was extracted from dried algae following the Bligh and Dyer method (Bligh and Dyer, 1959). The extracted lipid was further prepared as fatty acid methyl esters (FAME) via methylation. Afterward, sodium sulfate was added to remove the water, and the anhydrous sample was then injected into a gas chromatograph coupled with a flame ionization detector (GC-FID). Peak identification of the sample was performed via comparison with retention times of F.A.M.E. Mix, C4-C24 (Sigma-Aldrich) as a reference standard. For vitamin determination, the sample was subjected to the ultrasonic-assisted extraction method. Briefly, five grams of sample powder mixed with 55 mL of 4.76% ammonia solution were sonicated at 60°C for 30 min. The mixture was allowed to cool to room temperature and then the pH was adjusted to 7 using formic acid solution with volume adjusted to 100 mL. Thereafter, the obtained mixture was centrifuged at 3,000 rpm at 4°C for 10 min. The supernatant was filtered through a 0.45 µm membrane before further analysis. Carotenoid content was monitored using a normal-phase high-performance liquid chromatograph equipped with a UV-Vis spectrophotometer (Agilent Technologies). Chromatographic separation was performed using a Phenomenex silica gel column (3 µm, 150 mm × 4.6 mm, 100 Å) under the following condition: mobile phase: hexane/acetone (87:13, v/v) with flow rate 1.4 mL/min and elution time 20 min. Peaks were monitored at 450 nm (zeaxanthin) and 470 nm (astaxanthin). Vitamin A content was calculated on the basis of β-carotene content according to the method of Tee and Lim (1991) and then reported as Vitamin A (µg retinol equivalent). Contents of six water-soluble vitamins were determined using a high-performance liquid chromatograph (Waters Alliance 2695) equipped with an electrospray ionization probe-mass spectrometer (Micromass ZQ 2000) (HPLC/ESI-MS). Separation of the analyses was performed on a Spherigel C₁₈ reverse phase column (250 mm x 4.6 mm ID, 5 µm) (Johnson) according to the in-house method (Chen *et al.*, 2006). All the measured vitamins were calculated and expressed as mg/100 g dried sample except for thiamine and cobalamin those were presented in terms of µg/100 g dried sample.

Evaluation of gastroprotective activity in rats

Laboratory animals

Male Sprague-Dawley rats were obtained from the National Laboratory Animal Center, Salaya Mahidol University, Thailand. They were acclimatized for at least 7 days in an animal room, with temperature maintained at $22\pm 3^{\circ}\text{C}$ under a 12 h light-dark cycle. The animals had free access to water and standard diet (Perfect Companion, Bangkok, Thailand). All animals received human care in compliance with the ethics for the use of animals and the experimental procedures were approved by the Animal Ethics Committee, Faculty of Medicine, Chiang Mai University. The gastric ulceration experiment was conducted as three experimental models following the method of Amornlerdpison *et al.* (2009) with slight modifications.

Alga extraction

The collected alga, *Cc*, was cleaned to remove sand, clay and epiphytes, rinsed with distilled water and dried at 50°C for 48 h before milling. The milled alga was subsequently used to prepare the extracts. Milled material (100 g) was extracted in 2,500 mL of distilled water at 60°C for 24 h in a water bath adapted from Amornlerdpison *et al.* (2009). The crude extract was filtered through filter paper (Whatman No.1) and concentrated in a rotary evaporator at 40°C . Subsequently, the extracts were lyophilized as dried powder and dissolved in distilled water to the required concentrations.

Experimental models of gastric ulceration in rats

The study was performed to evaluate the gastroprotective activity of aqueous *Cc* (*Aq.Cc*) by employing various models of gastric ulceration in rats. Possible mechanisms involved in the activity were also examined in the three rat models. HCl/EtOH-induced gastric ulcers: After 48 h fasting, 18 rats weighing 200-250 g were randomly divided into 3 groups consisting of 1) control (distilled water), 2) 100 mg/kg of cimetidine (positive control) and 3) 500 mg/kg of *Aq.Cc*. A mixture of 1.0 mL HCl/EtOH (60 mL EtOH + 1.7 mL HCl + 38.3 mL H_2O) was orally administered to the rats to induce the formation of gastric lesions. After an hour of HCl/EtOH administration, the rats were sacrificed by intraperitoneal injection with pentobarbital sodium 100 mg/kg. Then, the stomach was removed and opened along the greater curvature. In the glandular portion of the stomach, the length in mm of each lesion was measured under a dissecting microscope (10X). The sum of the length of all lesions was designated as the ulcer index. Indomethacin-induced gastric ulcers: *Aq.Cc* 500 mg/kg, cimetidine and distilled water were orally administered into 3 groups of fasting rats. An hour after sample administration, indomethacin at a dose of 100 mg/kg was orally administered to the rats for induction of gastric lesions. After 5 h the rats were sacrificed

and examined for gastric ulcers as described above. Water immersion-restraint stress-induced gastric ulcers: The fasted rats were orally administered 500 mg/kg of *Aq.Cc* and cimetidine (a potent inhibitor of tubular creatinine secretion as the positive control) and distilled water. After an hour, the rats were restrained individually in stainless steel cages and immersed up to their xiphoid in a water bath maintained at $22\pm 2^{\circ}\text{C}$ for 5 h. The rats were then sacrificed and examined for gastric ulcers as described above.

Statistical analysis

The data were expressed as mean $\pm$ S.E.M. Statistical comparison between groups was analyzed using one-way analysis of variance, while for the post-hoc least significant difference test, *p* values less than 0.05 were considered significant.

Results

Local knowledge and species identification of Chara corallina

Morphological and molecular identification confirmed the specimens as *C. corallina*. The morphological characteristics of *Cc* are illustrated in Figure 1. We successfully obtained *rbcL* sequences (~1250 bp) from specimens C1 and C2. Both samples showed 99.92% genetic similarity to *C. corallina* from Japan (AB359167). Phylogenetic analyses (Figure 2) placed C1 and C2 in a well-supported clade with *C. corallina* (ML = 95%, BI = 0.95), which is closely related to *C. australis*.

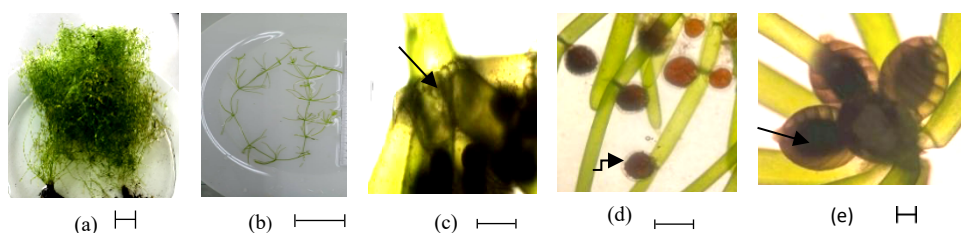


Figure 1. *Chara corallina* habitat and vegetative morphology. Plant in natural habitat (a, b), stipulode (c), antheridium (d), surface view of oogonium (e) Scale bars: 1.0 cm (a, b) and 100 μm , (c, d, e)

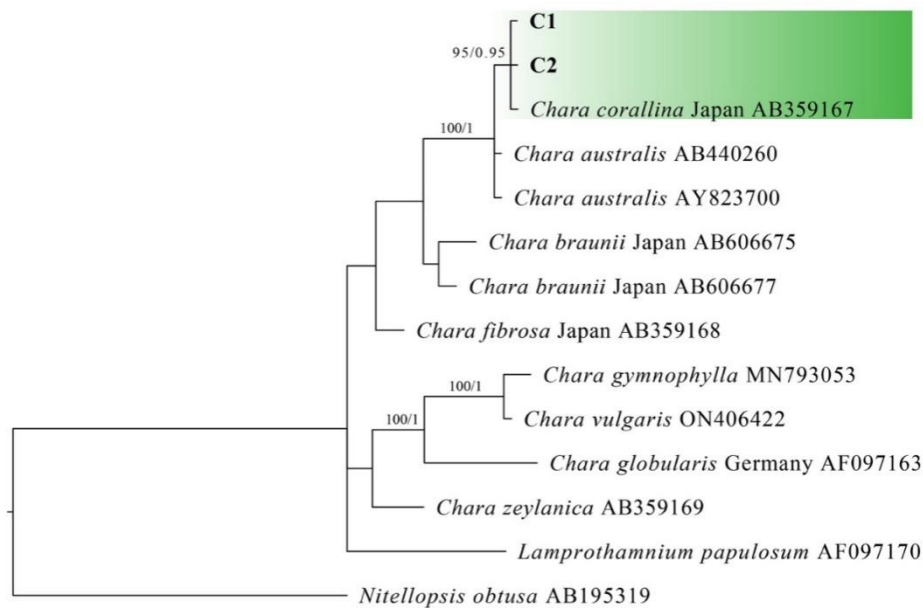


Figure 2. Maximum likelihood tree based on *rbcL* gene sequences showing the phylogenetic position of *Chara* specimens C1 and C2 from Thailand (bold). ML bootstrap values (left) and Bayesian posterior probabilities (right) are shown at nodes (>90% />0.90)

General information about the interviewees, together with the local knowledge of algal consumption as traditional food and related information was collected through by participatory action research involving ethnic group in the targeted area of Krabi Province, Thailand. In total, 43 interviews were conducted with 32 women and 11 men ranging in age from 24-92 years. Six of the women were classified as harvesters, while five were classified as sellers and the remaining interviewees were local villagers who consumed *Cc* in five districts of Krabi Province.

Local knowledge regarding algal consumption revealed that *Cc* is sold by local communities as a fresh vegetable in local markets, particularly by women in the Khlong Thom and Nuea Khlong districts of Krabi Province. Algal collection is typically carried out by men at multiple sites, including creeks and pond beds (Figure 3). Freshly harvested algae, yielding approximately 10.2–10.8 kg wet weight per person, are sold in local markets at a price of THB 20 per 100 g pack (Figure 3). Notably, the cultivation, processing, and sale of *Cc* in this area are exclusively managed by women.



Figure 3. The traditionally harvester (a, b) selling in the local market (c, d, e), cultivation (f), consumption of *Chara corallina* with chili paste (g, h)

Nutritional values

Chemical compositions and caloric energy of *C. corallina* is shown in Table 1.

Gastroprotective activity of Chara corallina extract in rats

Several experimental models including water immersion-restraint stress, HCl / EtOH induced gastric ulcers, are commonly used anti-ulcer activity in rats. Oral administration of 500 mg/kg of *Aq.Cc* exhibited a significant decrease in gastric lesions induced by three models in rats consisting of HCl / EtOH, indomethacin and water immersion-restraint stress. The *Aq.Cc* displayed inhibition of gastric ulcers at 53, 79 and 59% in the three rat models, similar to cimetidine, the positive control group and especially in the indomethacin model (Table 2).

Table 1. Nutritional profile of *Chara corallina*

<i>Proximate composition</i>	<i>(g/100 g dw)</i>	<i>Minerals</i>	
Moisture	14.15±0.01	<i>Macrominerals</i>	(mg/kg dry basis)
Protein	19.55±0.33	Calcium (Ca)	20,369.95±676.48
Lipid	2.54±0.01	Potassium (K)	26,213.45±525.45
Carbohydrate	38.82±0.26	Magnesium (Mg)	3,328.74±2.69
Crude fiber	7.29±0.27	Sodium (Na)	886.90±0.35
Ash	24.95±0.07	<i>Microminerals</i>	(mg/kg dry basis)
Energy	9.98±0.04	Manganese (Mn)	17,761.60±365.43
(KJ/g dry matter)		Iron (Fe)	24,630.35±565.61
<i>Amino acids</i>	(% of total amino acids)	Zinc (Zn)	44.32±0.30
Arginine	9.43±0.02	Selenium (Se)	1.39±0.20
Histidine	0.73±0.01	Chloride (Cl)	13,100±4.00
Isoleucine	4.14±0.04	Copper (Cu)	7.56±0.06
Leucine	7.09±0.08	<i>Vitamins*</i>	
Lysine	8.52±0.13	β-Carotene (μg Re)	≥5
Methionine	15.43±0.05	Ascorbic acid (mg)	13.1±0.00
Phenylalanine	3.18±0.40	Folic acid (mg)	4.39±0.01
Threonine	6.07±0.01	Pantothenic (mg)	2.37±0.11
Tryptophan	0.78±0.00	Riboflavin (mg)	0.80±0.08
Valine	4.86±0.07	Thiamine (μg)	≥3
Alanine	7.74±0.17	Cobalamin (μg)	3.44±0.06
Aspartic acid	6.86±0.02	<i>Fatty acids</i>	(mg/100 g dw) (% of total fatty acids)
Glutamic acid	0.65±0.01	C14:0	10.69±1.78 1.60±0.28
Glutamine	5.39±0.06	C16:0	340.11±16.58 50.89±1.88
Glycine	2.42±0.00	C18:0	46.07±2.85 6.89±0.35
Proline	5.38±0.07	C18:1n-9	49.30±4.52 7.38±0.37
Hydroxyproline	4.78±0.03	C18:2n-6	155.93±2.35 23.34±0.62
Serine	0.01±0.00	C18:3 n-3	42.55±5.35 6.38±0.87
Tyrosine	4.69±0.71	C20:4 n-6	23.50±0.88 3.52±0.15
Cystine	1.86±0.01	SFAs	59.40
Total essential amino acid (EAA)	60.23	Monounsaturated fatty acids (MUFAs)	7.38
		Polyunsaturated fatty acids (PUFAs)	33.24
Total non-essential amino acid (NEAA)	39.77	n-3 fatty acids	6.38
Ratio of EAA / NEAA	1.51	n-6 fatty acids	26.86
		n-9 fatty acids	7.38

Table 2. Gastroprotective activity of aqueous extract of *Chara corallina* in rats

Group	HCl / EtOH		Indomethacin		Restraint water immersion stress	
	Ulcer index (mm)	Inhibition (%)	ulcer index (mm)	Inhibition (%)	ulcer index (mm)	Inhibition (%)
Control	10.78±0.00	-	1.00±0.00	-	0.96±0.00*	-
Cimetidine (100 mg/kg)	2.91±0.00*	73	0.14.00±0.00*	86.0	0.29±0.00*	70.0
Aq.Cc (500 mg/kg)	5.06±0.02*	53	0.22±0.00*	79.0	0.39±0.00	59.0

Note: Data are expressed as mean ± S.E.M. (n = 6, significant difference from control group: * $p < 0.05$)

Discussion

Local knowledge of Chara corallina

Thailand is an agricultural country where, historically, the people lived off the land. They looked for natural food as plants and animals and cooked using simple methods. Thai people in rural or remote areas, especially Southern Thailand, prefer to consume edible vegetables with strongly spiced food, exemplified by chili paste, fish organs and sour soup. They balance the meals with many kinds of vegetables. Phak Wa (*Monochoria hastata*) and Kam Kung alga were recognized as representatives of vegetables as daily food for Thais. These two vegetables are normally found in rice fields. They are served as the main course or side dish for many occasions including religious ceremonies and funerals. In Krabi Province (focus area), Klong Tom and Nuea Klong district once had an abundance of *Cc* that has now decreased to a critical level. Major causes of decline in these water vegetables over the past two decades are the increase of systematic agriculture (Para rubber and oil palm plantations), land reform, public utility and housing development. Traditionally, this algal species was used for human health, especially to treat ailments of the digestive system. Interviews were carried out in the local markets as well as with people in five districts of Krabi Province to gather information about the dietary use of this alga. Interviews with local residents revealed that traditional ecological knowledge related to edible *Chara corallina*, including recognition of its natural habitats, identification of edible and inedible algae, harvesting techniques, and culinary uses, has been transmitted across generations through observation and practical experience. Similar patterns of knowledge transmission have been widely documented for other edible algae and wild edible plants, highlighting the importance of intergenerational learning in sustaining traditional food systems (Turner, 2003; Saensouk *et al.*, 2025; Luu *et al.*, 2025).

Nutritional values

The chemical composition of *Cc* was moderate protein content when compared with commercial algae such as *Spirulina* and *Chlorella* (more than 50 % dw) (Andrade *et al.*, 2018). The protein content of this sample was similar to some freshwater fish (Ministry of Public Health, Nutritive values of Thai foods, 2024) and higher than some edible green freshwater algae such as *Spirogyra varians* (12.0-24.4 % dw) (Chen *et al.*, 2006) and *Cladophora* sp. (10-17% dw) (Tipnee *et al.*, 2015). Lipid content of *Cc* was similar to several marine seaweeds (approx. 1-6 % dw) (Khuantrairong and Traichaiyaporn, 2011; Rameshkumar *et al.*, 2013). The macroalga studied had lipid content comparable to the edible green freshwater alga *Cladophora* sp. (2.04-2.56% dw) (Khuantrairong and Traichaiyaporn, 2011) but lower

than *Spirogyra varians* (18.1% dw) (Tipnee *et al.*, 2015) and *Chlorella* sp. (approx. 20 % dw) (Andrade *et al.*, 2018). Carbohydrate was a major component of *Cc*, but fiber content was low. Carbohydrates are considered the main energy source for the human body. Various carbohydrates derived from algae are categorized as functional ingredients with properties including antioxidant, anticoagulant and antiviral activities (Taboada *et al.*, 2013). Similar to other algae, *Cc* had higher ash content than terrestrial plants and animal products. Caloric energy provided by one gram of dried *Cc* was 9.98 kJ.

Protein is the most critical component contributing to nutritional value of food (Mišurcová *et al.*, 2014). Protein contributes to the nutritional value of the food, but the quality of protein is also governed by digestibility, availability and quantity of essential amino acids (Shuuluka *et al.*, 2013). Results in Table 1 showed that *Cc* contained a high proportion of essential amino acids (EAA) with high ratio of EAA/NEAA at 1.53. Methionine was identified as a major amino acid followed by arginine, lysine and leucine, while alanine, aspartic acid, glutamic acid and glycine were the most abundant non-essential amino acids (NEAA) in *Cc*. Generally, sulfur-containing amino acids are nutritionally important compounds and considered as limited amino acids of plant protein (Shuuluka *et al.*, 2013). Aspartic acid and glutamine are responsible for the umami taste, whereas glycine and alanine give a sweet taste (Running and Hayes, 2016).

Considering the fatty acid profile, *Cc* consisted of 59.40% saturated fatty acids (SFAs), 7.38% monounsaturated fatty acids (MUFAs) and 33.24% polyunsaturated fatty acids (PUFAs). Palmitic acid (C16:0) was the main fatty acid in *Cc* in agreement with other algae (Benjama and Masniyom, (2012); Shuuluka *et al.*, (2013); Running and Hayes, 2016). Interestingly, its PUFAs were mainly from C-18 fatty acids particularly essential fatty acids linoleic acid (C18:2 n-6) and α -linolenic acid (C18:3 n-3). Moreover, the n-6/n-3 ratio that the World Health Organization recommends should not exceed 10 in the diet (Taboada *et al.*, 2013) was established at 4.21.

High amounts of minerals (10.64 g/100g dw) were found in *Cc* including potassium, iron, calcium and manganese. This species possessed higher calcium and lower sodium content compared with Wakame and Nori (Taboada *et al.*, 2013). Remarkably, the calcium content of this macroalgae was equivalent to small fish intake. Results also showed that *Cc* had a high ratio of K/Na (29.5:1) that would help to reduce blood lipid, obesity and risk of coronary heart disease (Shuuluka *et al.*, 2013). Selenium, not normally presented in algae, was found in *Cc*. Selenium plays a key role in metabolism and thyroid functions. Small amounts of selenium intake can prevent cell damage caused by oxidative stress. Intake of this alga may overcome Ca deficiency, while the Fe content may promote children's growth and women's health. The binding of certain minerals to polysaccharides restrains their

absorption, although high affinity may be compensated by high mineral contents (Taboada *et al.*, 2013).

Regarding vitamins, *Cc* was a rich source of ascorbic acid concomitant with small amounts of β -carotene (vitamin A) and lack of tocopherol (vitamin E). These three vitamins are well known as antioxidants, with significant roles in neutralizing free radicals. Apart from antioxidant vitamins, this sample also offered a good source of vitamin B complex (folic acid, pantothenic, riboflavin, thiamin and cobalamin) particularly cobalamin (vitamin B12) that is unavailable in higher plants (Benjama and Masniyom, 2012). This alga sample showed potential as a source of cobalamin for strict vegetarians (Wells *et al.*, 2017), with also appreciable amounts of protein, carbohydrate and mineral contents as a source of calcium and essential amino acids, particularly methionine. Moreover, *Cc* also contained cobalamin and antioxidant constituents including selenium and ascorbic acid as a potential health food resource for human consumption.

Gastroprotective activity of Chara corallina extract in rats

Result found that the aqueous extract displayed inhibition of gastric ulcers at 53, 79 and 59% in the three rat models. Indomethacin causes gastric ulcers by inhibiting COX enzyme decreased in cytoprotective prostaglandin production. It also reduced bicarbonate secretion, production of mucous and decreases mucosal microcirculation (Murakami *et al.*, 1985; Robert *et al.*, 1979; Selling *et al.*, 1987). However, cimetidine showed a higher effect than the aqueous extract in the other two rat models. Cimetidine is a drug that reduces the secretion of gastric acid. It is used to alleviate symptoms of peptic ulcer disease and erosive gastroesophageal reflux disease (GERD) (Vane, 1971).

Gastric ulcers from EtOH / HCl caused severe damage to the gastric mucosa. Bands of hemorrhagic lesions along the long axis of the glandular stomach were found due to HCl causing severe damage to gastric mucosa (Scheinfeld, 2003), whereas ethanol produced necrotic lesions and reduced defensive factors such as secretion of bicarbonate and production of mucus (Yamahara *et al.*, 1988). Stress increases acid secretion and decreases gastric mucosal secretion. Water immersion-restraint stress reduced mucosal blood flow and mucus secretion in the gastric mucosa, resulting in the development of gastric lesions (Yamahara *et al.*, 1988). Findings suggested that *Aq.Cc* possessed gastroprotective activity that involved gastric acid and mucosal secretion.

Based on the findings of this study, *Cc* showed strong potential as a promising food source. Further development of greenhouse cultivation techniques will be essential, along with expanding its utilization through the development of high value-added products.

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Conflicts of interest

The authors declare no conflicts of interest.

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