MINERAL CONTENT AND PHYTOCHEMICAL PROPERTIES OF SELECTED *CAULERPA* SPECIES FROM MALAYSIA

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ABSTRACT Seaweeds are abundant and are an important renewable resource for the coastal community since they are rich sources of minerals and natural bioactive compounds. Among them, the *Caulerpa* species under green seaweeds is widely consumed by locals in Southeast Asia. Edible seaweeds are often associated with various health benefits. However, in Malaysia, limited studies have been done on the mineral and antioxidant levels of seaweeds, especially for the *Caulerpa* species. Thus, the present study aimed to evaluate the variations of minerals and antioxidants of selected *Caulerpa* species in Malaysia. The samples were collected in two study sites, which were Blue Lagoon, Port Dickson and Merambong Shoal, Johor. Two species, *C. racemosa* and *C. manorensis* were recorded from Merambong Shoal, Johor, while five species were recorded namely *C. sertularioides*, *C. racemosa var lamourouxii*, *C. lentillifera*, *C. racemosa var cylindracea* and *C. racemosa* at Blue Lagoon, Port Dickson. Among all the *Caulerpa* species from both study sites, *C. manorensis* possessed the highest phosphorus content (139.54 mg/100g) while *C. racemosa* from both Merambong and Blue Lagoon Port Dickson's calcium (Ca) content was significantly highest at 2318.33 – 2406.66 mg/100g. All the *Caulerpa* species possessed high sodium (Na) content ranging 9338.30 – 21748.30 mg/100g. For micronutrients, the highest zinc content was recorded in *C. manorensis* (3.40 mg/100g) while the copper content was significantly highest in *C. racemosa* from Port Dickson (1.05 mg/100g). The methanol extract of *C. sertularioides* possessed phytochemical attributes of high antioxidant activity (DPPH EC_{50} = 24.16 mg/mL) with a high FRAP value being recorded in *C. lentillifera* (27.09 mg TE/100g). The TPC and TFC were highest in *C. lentillifera* with 57.95 mg GAE/100g and 1506.41 mg QE/100g respectively. The present study revealed that *Caulerpa* species contained constituents with significant mineral compositions and phytochemical attributes suitable for pharmaceutical and nutraceutical uses.

Keywords: Seaweeds, mineral content, total flavonoid content, antioxidant, total phenolic content.

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1. INTRODUCTION

Seaweeds are known as a group of plants under diverse algal classifications. They are mainly classified into Chlorophyta, Phaeophyta and Rhodophyta, based on their pigmentations, (green, brown and red) (Mohamed et al., 2012). Rhodophyta consists of 6000 species and is the most abundant compared to Chlorophyta (1200 species) and Phaeophyta (200 species) (Venugopal, 2011). As a primitive plant, seaweed does not produce flowers; instead, it relies on spores to spread. The plant produces thallus formations that are root-like, leaf-like and stem-like. Seaweeds are important marine renewable resources which are rich sources of minerals and natural bioactive compounds (Kamaladhasan and Subramanian, 2009; Selvaraj et al., 2010; Domettila et al., 2013). The marine algae in Malaysia, according to Phang et al., (2006), consist of 381 species with 105 species from Chlorophyta, 186 species from Rhodophyta, 73 species from Phaeophyta and 17 taxa from Cyanophyta.

The *Caulerpa* species is widely distributed in Malaysia and is often consumed as a raw salad by the locals, especially in Sabah and Sarawak (Du et al., 2009; Phang et al., 2005; Phang et al., 2008; Gan et al., 2011; Thilahgavani and Charles, 2014; Zawawi et al., 2015), especially *C. lentillifera* and *C. racemosa*, also known as "sea grape" or called locally as 'Latok' (Nagappan and Vairappan, 2014; de Gaillande et al., 2017; Yap et al., 2019).

The seaweeds under the genus *Caulerpa* are characterised as coenocytic, where a single cell contains many nuclei. This species is often found attached to rocks, coral rubble and sometime on sandy to muddy substrates. Due to its diverse adaptation, this species is invasive by nature (Jousson et al., 2000; Ramesh et al., 2012). Research had been conducted on various seaweed species to explore their potential for human consumption and as live feed (Zemke-White and Ohno, 1999; Dinabandu and Charles, 2005; Matanjun et al., 2008; 2009). Seaweed species are also known for being high in non-starch polysaccharides and possess ample minerals, fatty acids, antibiotics, amino acids with phytochemical properties which are useful for pharmaceutical and nutraceutical applications (Cavas and Pohnert, 2010; Matanjun et al., 2008; Mabeau and Fleurence, 1993; Yow et al., 2011).

Although, many seaweed species had been studied, limited research reports documented the minerals and antioxidant activities of *Caulerpa* species, especially in Malaysia. The diversity in the biochemical composition of *Caulerpa* provides an opportunity for further exploration of this seaweed (Holdt and Kraan, 2011). There is a need for more information to better understand the nutritional profiles of the exact species consumed and their biological potentials. An in-depth systematic assessment of selected species of *Caulerpa* that describes their nutritional values and the presence of phytochemical compounds is an important aspect to better understand their significance as a marine salad and functional food. The aims of this study were to evaluate the mineral contents and phytochemical attributes of selected *Caulerpa* species in Malaysia.

2. METHODS

2.1 Sample collection

The *Caulerpa* species namely, *C. racemosa*, *C. manorensis*, *C. sertularioides*, *C. racemosa* var *lamourouxii*, *C. lentillifera*, *C. racemosa* var *cylindracea* were collected from Merambong Shoal, Johor (1°20'52.2"N, 103°35'53.6"E) and Blue Lagoon, Port Dickson (2°32'00.0"N 101°55'00.0"E) from April to September 2018 during low tide. The samples were then transported to the laboratory for further processing. The samples were washed with running seawater to remove the debris attached and they were then dried under room temperature (25-29°C) for 2 to 4 days. The dried *Caulerpa* species were then ground using a pestle and mortar and were kept in a sealed bag and stored inside a desiccator prior to further analysis.

2.2 Mineral analysis

2.2.1 Sample preparation

The atomic absorption spectrophotometric (AAS) method was used to determine the levels of the minerals sodium

(Na), magnesium (Mg), calcium (Ca), zinc (Zn) copper (Cu) and potassium (K) (AOAC, 2000). Prior to the mineral analysis, the samples were ashed using the dry ashing method 930.05 following AOAC, (2000), to eliminate organic substances, leaving pure inorganic residues (minerals). Air dried samples were incinerated in a furnace (550ºC) for 5-6 hours to obtain the ash values. The ash obtained was wetted with two drops of distilled water. This was accompanied by the addition of 2 ml of concentrated HCL and evaporated on a hot plate to dryness. The samples were then added with 10 ml of 20% HNO_3 and evaporated until half of the solution was left. The crucible was allowed to cool before the samples were moved into a volumetric flask and the volume was rendered to 100 ml. The extract was used for mineral content analysis.

2.2.2 Determination of macro- and micronutrients

For the determination of macronutrients (Na, K, Ca, Mg,), the sample extract was diluted by 100 factor dilution, whereas the original extract was used for micronutrient determination (Cu and Zn). The standard calibration range for K , Ca, Na and Cu was 0 , 1, 3, 5 ppm (0, 0.1 , 0.3, 0.5 ppm for Mg; 0, 1 , 2, 3 ppm for Cu). The samples were then analysed using the PerkinElmer AnalystTM 800 Atomic Absorption Spectrophotometer (AAS).

2.2.3 Determination of phosphorus (P)

Total Phophorus (P) was identified using the UV-VIS spectrophotometer colorimetric method (UNICO, New Jersey, USA). The sample's P concentration was quantified by measuring the color intensity provided by the sample against the standard solutions with known phosphorus concentrations using a standard curve. The Perkin Elmer Lamda 25 UV / Vis Spectrophotometer was used to measure the sample absorbance.

2.3 Phytochemical analyses

2.3.1. Sample preparation and extraction

A total of 5 g of ground samples were weighed and extracted for 3 days with 250 ml of 80 per cent methanol. The extraction was carried out with the assistance of an orbital shaker positioned at 160 rpm to facilitate further extraction. Afterwards, the samples were centrifuged at 500 element g for 10 min. The supernatant was filtered using no. 2 Whatman filter pad A Rotary Evaporator was used to evaporate the remaining solvents.

The sample extracts were moved to a flask for distillation. The evaporation was conducted at a decreased pressure of 110 hPa and rotated in a water bath at a speed of 4 at 35°C. At the condenser, the residual solvent (methanol) was stored. Extracts of crude samples were stored at 4°C until analysis.

2.3.2 DPPH radical scavenging activity assay

The overall antioxidant activity (TAA) of the plant extracts from *Caulerpa* against DPPH radicals was determined using the methods adapted by Brand-Williams et al., (1995). A 100 microns DPPH stock solution was formulated using pure methanol. The sample extracts were diluted with 80 percent methanol to a series of known concentrations. One ml of isolated sample was added to DPPH solution of 3.0 mg. The solutions were incubated under dark conditions for 30 min at room temperature. Using an UV/Vis spectrophotometer, the sample absorbance was measured at 517 nm. A lower EC50 value indicated a higher antioxidant activity. Trolox was used as a standard.

2.3.4 Ferric reducing antioxidant power assay (FRAP)

Ferric reduction of the antioxidant power of the extract was determined using the

FRAP test following the modified method by Benzie and Strain, (1996). Trolox was used as a standard working reagent, and TPTZ was used as a blank reference. Using the UV/Vis Spectrophotometer, the absorbance of sample and the standard was read at 595 nm. The standard curve was made from a Trolox concentration range of 0-100 μmol. The findings were presented in milligrams (mg) trolox equivalent (TE)/100 g.

2.3.5 Total phenolic content (TPC)

The Folin - Ciocalteau spectrophotometric approach as described in Singleton and Rossi, (1965) and Ramaiya et al., (2013) was used to determine the total phenolic content in extracts of *Caulerpa* species. Gallic acid was used as the standard of reference. The sample absorbance was measured at 740 nm against the standard for gallic acid. The total phenolic content of a sample was expressed as milligrams (mg) of gallic acid equivalent (GAE)/100 g.

2.3.6 Total flavonoid content (TFC)Total flavonoid content (TFC), as defined by Jia et al., (1999), was calculated using an updated colorimetric test. The following experiments were carried out under ambiguous conditions. After 15 min reaction, the absorbance was measured at 510 nm. Quercetin was the standard used, and the data were expressed as milligram (mg) quercetin equivalents (QE)/100 g.

2.4 Statistical analysis

A single-factor variance analysis (ANOVA) with post hoc Duncan test (p<0.05) was used to compare the average analytical values for minerals and phytochemicals. EC_{50} values for TAA were calculated by using linear regression analysis.

3. RESULTS AND DISCUSSION

Different *Caulerpa* species were observed to grow together at the natural habitat. The *Caulerpa* species were observed to inhabit the rocky shore by attaching their holdfasts onto the rocks and coral crush at the sampling locations (**Figure 1**).

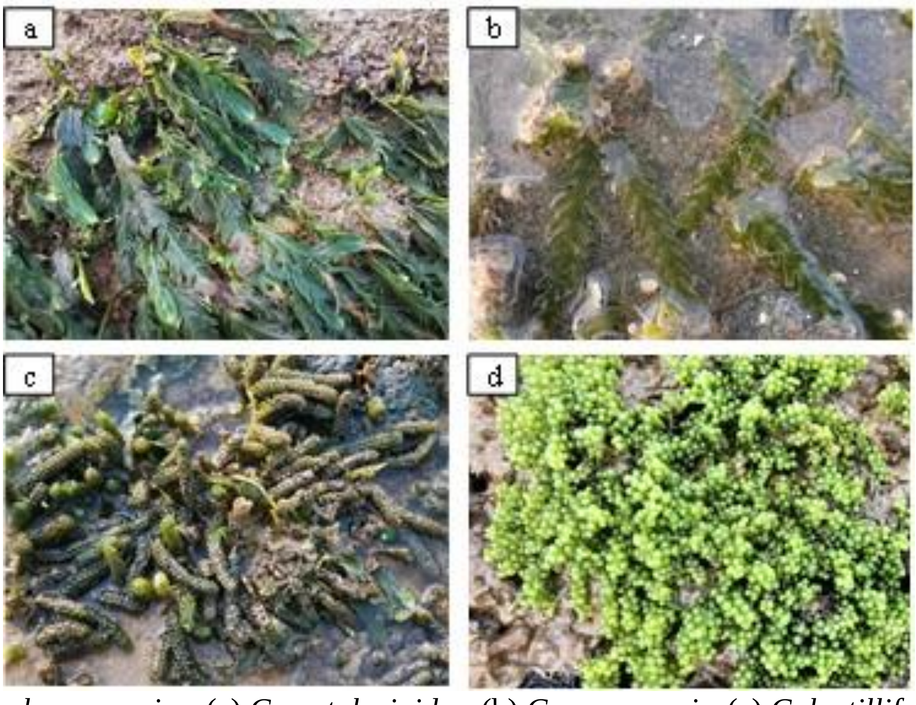

Figure 1. *Caulerpa* species, (a) *C. sertularioides*, (b) *C. manorensis*, (c) *C. lentillifera* and (d) *C. racemosa* at the natural habitat.

The observations on the study area showed that at Merambong Island, Johor, two *Caulerpa* species were recorded i.e., *C. racemosa* and *C. manorensis*, which grew side by side and were associated with other seaweeds. Meanwhile, at Blue Lagoon, Port Dickson, five *Caulerpa* species were observed, *C. sertularioides*, *C. lentillifera*, *C. racemosa, C. racemosa* var *Lamourouxii* and *C. racemosa* var *cylindracea*. The *Caulerpa* species at both the areas showed associations with other seaweeds and could be found side by side e.g., *Gracilaria* sp., *Solieria robusta*, and *Padina* sp. Although they shared the same habitat, there were differences in their biochemical contents (Sarini et al., 2014).

3.1 Mineral contents of Caulerpa species

The mineral contents of the *Caulerpa* species are presented in Table 1. The results showed that the *Caulerpa* species had significant variations of macro- and micronutrients among different species or locations. Among the macronutrients, *C. manorensis* from Merambong possessed higher phosphorus (P) (139.54±2057 mg/100 g) compared to *C. racemosa* from Merambong and Port Dickson which possessed the least P content; 77.20±8.00 and 75.83±7.88 mg/100 g, respectively. Pattama and Anong, (2006) reported that *C. lentillifera* from Pattani Bay, Thailand contained higher P compositions 1030.00 mg/100 g compared to the present studied species of *C. lentillifera* from Port Dickson (112.29±14.79 mg/100 g).

The sodium (Na) value is expected to be high in seaweeds as they grow in a saline environment compared to the value reported for terrestrial plants (USDA, 2001). Ruperez (2002) reported the Na contents for five species of seaweeds ranged between 3818±48 to 7064±166 mg/100 g. Na content was higher in *C. racemosa* from Merambong Shoal with 21748.30±1259.66 mg/100 g, while *C. lentillifera* from Port Dickson showed lower Na content of 9338.30±183.87 mg/100 g. Excess salt residue might interfere with the higher Na result caused by the air dry method. Although sodium is necessary in a healthy daily diet, its high intake has been correlated to the prevalence of hypertension (Ruperez, 2002). Calcium (Ca) in the *Caulerpa* species varied between species and locations. *Caulerpa racemosa* from Merambong and Port Dickson showed higher Ca content; 2318.33±94.51 mg/100 g and 2406.66±17.55 mg/100 g, respectively. Rasyid, (2017) reported that the Ca in *Ulva lactuca* was 1828 mg/100 g, while *C. lentillifera* was reported by Pattama and Anong, (2006) to contain 780 mg/100g which was much lower than the studied species of *C. lentillifera* from Port Dickson (1186.66±32.53 mg/100 g).

For micronutrients, Zinc (Zn) was higher in *C. manorensis* from Merambong with 3.40±1.13 mg/100 g and was lower in *C. sertularioides* from Port Dickson with (1.05±0.86 mg/100 g). The Zn values of *C. lentillifera* from Port Dickson was 1.45 mg/100 g and this was two times lower than the value reported by Pattama and Anong, (2006) of 2.6 mg/100 g. For copper (Cu) composition, *C. racemosa* from Port Dickson showed a higher value with 24.10±0.13 mg/100 g, while *C. manorensis* showed the least Cu content with 12.56±0.96 mg/100 g. Generally, the Cu contents of brown and red seaweeds were higher compared to green seaweeds. Ruperez, (2002) reported that three brown seaweeds and two red seaweeds contained less than 0.5 mg/100 g. Zinc and copper are considered as heavy metals. All the *Caulerpa* species mentioned above showed the accepted levels of Zn and Cu for human consumption in Japan and France; 15.0 and 10.0 mg/100 g, respectively (Indegaard and Minsaas, 1991; Ruperez, 2002). The variations among species and locations were difficult to explain as the mineral contents of seaweeds were reported to be varied according to species, *in-situ* water quality, location of habitat, wave activity, seasonal, environmental and physiological factors, sample handling, and method of mineralization (Ruperez, 2002; López et al., 2013; Norra et al., 2017).

3.2 Recommended daily allowance (RDA)

The recommended daily allowances (RDA) for human males and females (19 to 30-year-olds) are presented in Table 2 for macronutrients and Table 3 for micronutrients. A plate of serving or equivalent of 10 g dry weight of *Caulerpa* species provided a macronutrient range of phosphorus between 7.58 - 13.95 mg / 10 g, 1.08 – 1.99 (%), less than 28.70% of the RDA for both genders. Phosphorus intake is vital to the fundamental process of body metabolism and helps in bone and teeth development (Wardlaw, 2003).

Potassium ranged between 66.16 – 141.00 mg / 10 g, 1.40 – 3.00 (%) less than 10.00% of the RDA for both genders. Together with Na, K also is an essential element for body regulation and electrolyte balance in the human body (Krishnaiah et al., 2008). Calcium ranged between 114.00 – 240.66 mg / 10 g, 11.40 - 24.06 (%) higher than 3.40 % of the RDA for both genders. Ca is essential in bone formation and strength and is involved as a co-factor in enzyme systems (Martin, 1997; Wardlaw, 2003). Magnesium ranged between 62.83 – 93.00 mg / 10 g, 14.96 - 22.14 (%), less than 24.60 % of the RDA for male and 19.63 – 29.06 (%) less than 32.30 % of the RDA for female. Together with Ca, Mg is important for neurochemical transmission and muscle excitability (Wardlaw 2003; Ramaiya et al., 2019) (Table 2).

The micronutrient content for 10 g dry weight of *Caulerpa* species showed sodium ranged between 674.67 - 2174.83 mg/10 g, which was 62.25 – 144.98 (%) higher than 0.51 % of the RDA for both genders. Sodium intake is important for the maintenance of plasma and extracellular fluid. Excess sodium in the diet leads to several conditions such as heart attack, failure, disease and stroke (Lloyd-Jones et al., 2010; Benjamin et al., 2019). Copper ranged between 1.14 – 2.41 mg / 10 g, 126.66 – 256.22 (%) higher than 103.60 % of the RDA for both genders. Some seaweeds were reported to have high abilities to absorb heavy metals (Besada et al., 2019).

Zinc ranged between 0.10 – 0.34 mg / 10 g, 0.95 – 3.09 (%) less than 11.60 % of the RDA for male and 1.31 – 4.25 % less than 16.00 % of the RDA for female. Zn is essential for growth and development as it is needed in gene expression, DNA synthesis, RNA synthesis and cell division (Salgueiro et al., 2002) (Table 3). Although from the same species, the nutrient contents might be different due to geographical locations and environmental effects (Wardlaw, 2003).

Table 1. Macro and micro mineral contents in *Caulerpa* species.

***Caulerpa* species**	**Phosphorus (P)**	**Sodium (Na)**	**Magnesium (Mg)**	**Potassium (K)**	**Calcium (Ca)**	**Zink (Zn)**	**Copper (Cu)**
C. sertularioides Port Dickson	123.33±14.34^{ab}	13043.30±47.52^{d}	901.66±35.47^{a}	1046.66±55.07^{b}	1140.00±30.41^{e}	1.05±0.86^{d}	11.40±0.30^{f}
C. racemosa var *lamourouxii*, Port Dickson	115.66±7.94^{ab}	20550.00±562.91^{b}	915.00±35.00^{a}	1365.00±74.66^{a}	1538.33±27.53^{c}	2.05±1.64^{b}	15.05±0.35^{d}
C. lentillifera, Port Dickson	112.29±14.79^{bc}	9338.30±183.87^{e}	788.33±22.54^{b}	661.66±68.98^{d}	1186.66±32.53^{d}	1.45±1.41^{dc}	11.88±0.35^{ef}
C. racemosa, Merambong	77.20±8.00^{d}	21748.30±1259.66^{a}	690.00±27.83^{c}	1168.33±106.10^{b}	2318.33±94.51^{a}	1.60±1.33^{bcd}	23.06±0.93^{b}
C. racemosa var *cylindracea* Port Dickson	90.45±12.24^{cd}	17423.30±80.20^{c}	930.00±30.00^{a}	1410.00±72.11^{a}	1718.33±94.38^{b}	1.20±1.12^{cd}	16.45±0.52^{c}
C. racemosa, Port Dickson	75.83±7.88^{d}	13946.70±163.57^{d}	686.66±59.65^{c}	1163.33±65.06^{b}	2406.66±17.55^{a}	1.70±1.51^{bc}	24.10±0.13^{a}
C. manorensis, Merambong	139.54±2057^{a}	16746.70±27.53^{c}	628.33±17.55^{c}	861.66±36.17^{c}	1266.66±95.04^{d}	3.40±1.13^{a}	12.56±0.96^{e}

Different superscript alphabets in the same column display variations at $p<0.05$ (ANOVA, DNMRT Test). Values are given as the mean (mg) ± standard deviation, and values are the range in parentheses.

Table 2. Macronutrients of *Caulerpa* species per serving (mg / 10 g) and percentage (%) of RDA for *♂-male, ♀-female, 19- 30 years old.

Species	Phosphorus		Potassium		Calcium		Magnesium		
	Mineral (mg/10g)	19-30 y/o ♂♀ RDA 28.70 %	Mineral (mg/10g)	19-30 y/o ♂♀ RDA 10.00 %	Mineral (mg/10g)	19-30 y/o ♂♀ RDA 3.40 %	Mineral (mg/10g)	19-30 y/o ♂ RDA 24.60 %	19-30 y/o ♀ RDA 32.30 %
C. sertularioides Port Dickson	12.33	1.76	104.66	2.22	114.00	11.40	90.16	21.46	28.17
C. racemosa var *lamourouxii*, Port Dickson	11.56	1.65	136.50	2.90	153.83	15.38	91.5	21.78	28.59
C. lentillifera, Port Dickson	11.22	1.60	66.16	1.40	118.66	11.86	78.83	18.76	24.63
C. racemosa, Merambong	7.72	1.10	116.83	2.48	231.83	23.18	69.00	16.42	21.56
C. racemosa var *cylindracea* Port Dickson	9.04	1.29	141.00	3.00	171.83	17.18	93.00	22.14	29.06
C. racemosa, Port Dickson	7.58	1.08	116.33	2.4	240.66	24.06	68.66	16.34	21.45
C. manorensis, Merambong	13.95	1.99	86.16	1.83	126.66	12.6	62.83	14.96	19.63

Table 3. Micronutrients of *Caulerpa* species per serving (mg / 10 g) and percentage (%) of RDA for *♂-male, ♀-female, 19- 30 years old.

Species	Sodium		Copper		Zinc		
	Mineral (mg/10g)	19-30 y/o ♂♀ RDA 0.51%	Mineral (mg/10g)	19-30 y/o ♂♀ RDA 103.60%	Mineral (mg/10g)	19-30 y/o ♂ RDA 11.60%	19-30 y/o ♀ RDA 16.00%
C. sertularioides Port Dickson	1304.33	86.95	1.14	126.66	0.10	0.95	1.31
C. racemosa var *lamourouxii*, Port Dickson	2055.00	137.00	1.50	167.22	0.20	1.86	2.56
C. lentillifera, Port Dickson	933.83	62.25	1.18	132.00	0.14	1.31	1.81
C. racemosa, Merambong	2174.83	144.98	2.30	256.22	0.16	1.45	2.00
C. racemosa var *cylindracea* Port Dickson	1742.33	116.15	1.64	182.77	0.12	1.09	1.50
C. racemosa, Port Dickson	1394.67	92.97	2.41	267.77	0.17	1.54	2.12
C. manorensis, Merambong	674.67	44.97	1.25	139.55	0.34	3.09	4.25

3.2 Antioxidant activity of Caulerpa species

3.2.1 DPPH radical scavenging activity

Figure 2 shows the graph of DPPH scavenging activities of selected *Caulerpa* species based on the result of half-maximal effective concentration (EC_{50}). The lower the value of EC_{50}, the higher the antioxidant activity. The results showed that *C. sertularioides* possessed the highest antioxidant activity (24.16 mg/mL), while the lowest was recorded in *C. racemosa var cylindracea* with 62.88 mg/mL. However, other species showed moderate results of antioxidant activities. The antioxidant activities of *C. lentillifera* and *C. racemosa* species were 27.77 mg/mL and 32.91 mg/mL, comparatively lower than those of previous studies where *C. lentillifera* was 9.74 mg/mL and *C. racemosa* from Port Dickson was 2.51 mg/ml (Yap et al., 2019). The results from this present analysis indicated that the variability could be due to the disparity in habitat and process of preparing samples. The degree of antioxidants present in plants is strongly affected by genetics, climate, phases of growth, cultivation method, and the analysis tool used (Zhou and Yu, 2004).

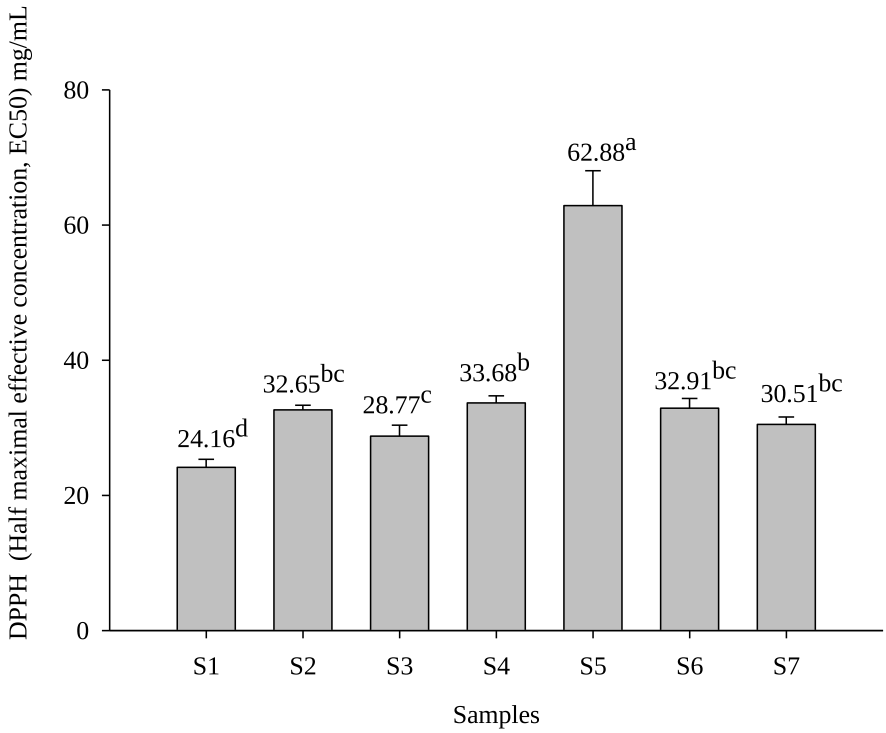

Figure 2. DPPH Radical Scavenging activities of *Caulerpa* sp.; *C. sertularioides* (S1), *C. racemosa* var *lamourouxii* (S2), C. *lentillifera* (S3), *C. racemosa*, Merambong (S4), *C. racemosa* var *cylindracea* (S5), *C. racemosa*, Port Dickson (S6) and *C. manorensis* (S7). Mean ± SD with the same alphabet is not significantly different (DNMRT, p>0.05).

3.2.2 Ferric reducing antioxidant power (FRAP)

The FRAP was used to detect the reducing power related to the degree of hydroxylation and the extent of polyphenol conjugation (Ou et al., 2002). FRAP is an important indicator to evaluate the antioxidant potential of seaweed extracts (Vinayak et al., 2001). The reducing power of *Caulerpa* species is expressed as mg TE/100g extract in Figure 3. *C. lentillifera* showed higher FRAP value (27.09 mg TE/100 g), while *C. racemosa* var *cylindracea* showed lower FRAP value (11.18 mg TE/100 g). The brown seaweed, *Himanthalia elongate*, showed a reducing power range of between 470 – 1170 mg TE/100 g (Rajauria et al., 2012). Brown seaweeds are known for their high FRAP values (Matajun et al., 2008; Mole and Sabale, 2013). Meanwhile, Dovi et al., (2012) reported that green seaweeds are the second highest after brown seaweeds and red seaweeds possess the lowest FRAP values.

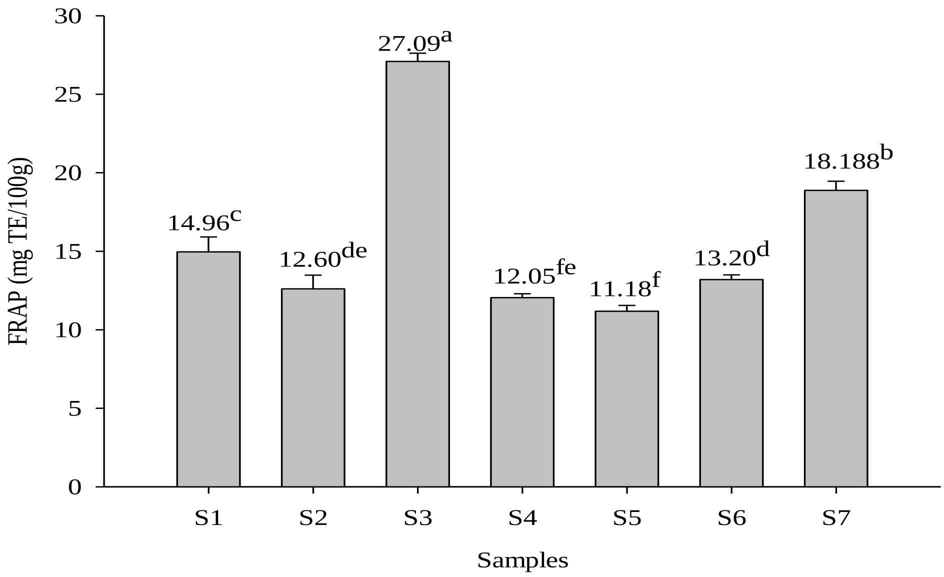

Figure 3. Ferric reducing ability of plasma (FRAP) assay of *Caulerpa* sp.; *C. sertularioides* (S1), *C. racemosa* var *lamourouxii* (S2), *C. lentillifera* (S3), *C. racemosa*, Merambong (S4), *C. racemosa* var *cylindracea* (S5), *C. racemosa*, Port Dickson (S6) and *C. manorensis* (S7). Mean ± SD with the same alphabet is not significantly different (DNMRT, p>0.05).

3.2.3 Total phenolic content (TPC) of Caulerpa species

The TPC results of *Caulerpa* species are shown in Figure 4. *Caulerpa lentillifera* showed higher TPC value compared to the TPC values of *C. racemosa* from Merambong at 57.95 mg GAE/100g TPC and at 15.76 mg GAE/100g (Figure 4). Chia et al. (2015) reported that *C. racemosa* from Port Dickson contained a TPC value of 19.80 mg GAE/100g which was slightly lower compared to *C. racemosa* from the present study at 27.43 mg GAE/100g. Chia et al., (2015) also reported that brown seaweeds such as *P. tetrastromatica* and *T. ornate* had higher TPC of 69.5 and 71.3 mg GAE/100g compared to the green algae. Different studies reported that phenolic compounds have high propensities for antioxidant, anti tumor, anti-inflammatory and antiviral actions that can impact human health (Novoa et al., 2001; Thomas and Kim, 2011; Ahmad et al., 2012 Wijesingher and Jeon, 2012). The high TPC in seaweeds might be contributed by the presence of multiple phenolic groups to overcome rising oxidant levels resulting from environmental stress (Airanthi et al., 2010), temperature (Ramah et al., 2013) and salinity (Berns, 2003).

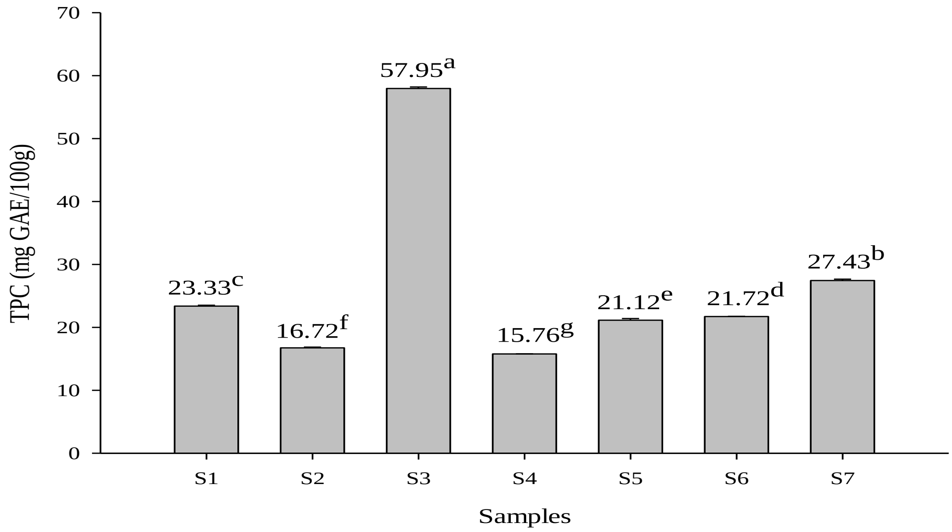

Figure 4. Total phenolic content (TPC) of methanolic extract of *Caulerpa* sp.; *C. sertularioides* (S1), *C. racemosa* var *lamourouxii* (S2), C. *lentillifera* (S3), *C. racemosa*, Merambong (S4), *C. racemosa* var *cylindracea* (S5), *C. racemosa*, Port Dickson (S6) and *C. manorensis* (S7). Mean ± SD with the same alphabet is not significantly different (DNMRT, p>0.05).

3.2.4 Total flavonoid content (TFC) of Caulerpa species

The TFC values for selected *Caulerpa* species from Merambong and Port Dickson are presented in Figure 5. *Caulerpa lentillifera* from Port Dickson had the significantly highest TFC value of 1506.41 mg QE/100 g compared to the other samples, while *C. racemosa* var *cylindracea* from Port Dickson showed the lowest TFC value of 305.57 mg QE/100 g. Yap et al., (2019) reported that *C. lentillifera* from Port Dickson contained a TFC value of 493.00 mg QE/100 g, while Chia et al., (2015) reported that *C. lentillifera* from Port Dickson showed a TFC value of 1600.00 mg QE/100 g when using the ethyl acetic method extraction.

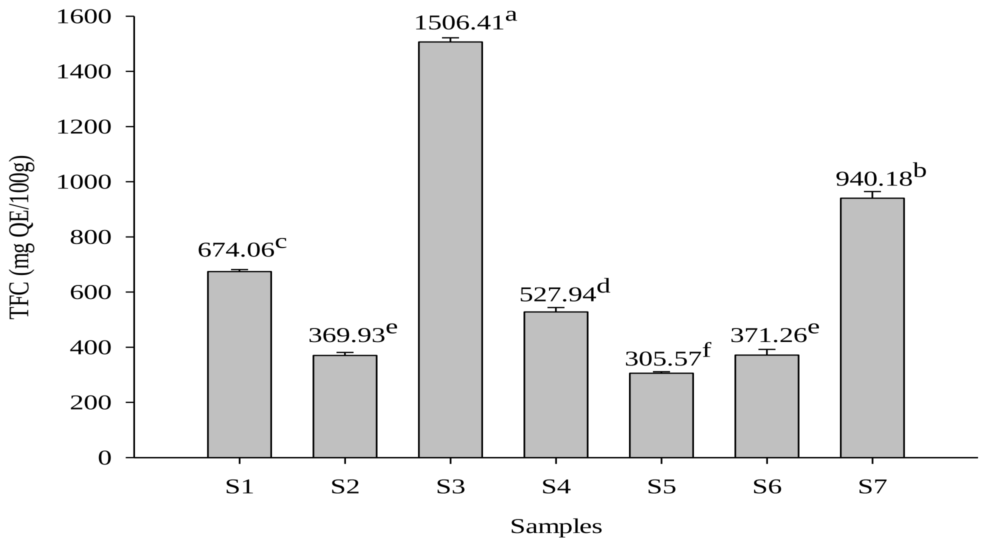

Figure 5. Total flavonoid content (TFC) of methanolic extract of *Caulerpa* sp.; *C. sertularioides* (S1), *C. racemosa* var *lamourouxii* (S2), C. *lentillifera* (S3), *C. racemosa*, Merambong (S4), *C. racemosa* var *cylindracea* (S5), *C. racemosa*, port Dickson (S6) and *C. manorensis* (S7). Mean ± SD with the same alphabet is not significantly different (DNMRT, p>0.05).

4. CONCLUSIONS

The present findings showed that *Caulerpa lentillifera* and *Caulerpa racemosa* possessed ample minerals and phytochemicals which could provide specific health benefits for human on consumption. Besides that, the presence of good minerals and antoixidant properties in other C*aulerpa* species also further added value to their potential in the pharmaceutical and nurtraceutical industries. It is suggested that a detailed exploration of the bioactive compounds, palatability, and anti-nutritional properties of *Caulerpa* species is important to fully understand the worth of this seaweed.

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