Nutritional Value of *Caulerpa lentillifera*

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Caulerpa lentillifera is a type of green seaweed widely consumed as a fresh vegetable, specifically in Southeast Asia. Interestingly, this green seaweed has recently gained popularity in the food sector.

Caulerpa lentillifera sea grapes nutrient content nutrient composition

1. Introduction

In 2019, Asia contributed to 97.4 percent of global seaweed production (99.1 percent from cultivation), with seven of the top ten producing countries located in Eastern or South-eastern Asia [1]. This indicates a significant regional imbalance in seaweed production which is largely influenced by the fact that seaweeds are a regular part of human diets in East Asia compared to elsewhere [2]. Seaweeds have been a food source since the fourth century in Japan and the sixth century in China. According to historical sources, people gathered macroalgae for sustenance as early as 500 B.C. in China and a thousand years later in Europe. People who lived near coastal areas preferred to consume seaweeds as a main dish or in soup [3]. Europeans usually consume smaller amounts of seaweed than Asians due to European regulations and dietary habits [4].

Although macroalgae intake is not as prevalent in Europe as in Asia, microalgae have acquired popularity because of their physiologically active components, earning them the reputation of "new superfoods" [5]. Between 1950 and 2019, global seaweed cultivation and production increased by a thousand-fold, with mainly brown seaweed (from 3.1 million tonnes to 16.4 million tonnes) and red seaweed cultivation (from 1 million tonnes to 18.3 million tonnes) being the main contributors [1]. However, the world cultivation of green seaweed decreased from 31,000 tonnes to 17,000 tonnes during the same period [2]. The 16,696 tonnes of green seaweeds grown in 2019 represented only 0.05 percent of the total seaweed production in the same year. Among the 16,696 tonnes produced were *Caulerpa* spp., *Monostroma nitidum*, *Enteromorpha* [*Ulva*] *prolifera*, *Capsosiphon fulvescens*, and *Codium fragile*, all of which are included in FAO’s Aquatic Sciences and Fisheries Information System. Out of 100 known *Caulerpa* species, only seven are utilised for human consumption globally, with *C. lentillifera* and *Caulerpa racemosa* dominating in this aspect [6]. **Table 1** shows the global seaweed production and comparison by region in 2019.

Table 1. Global seaweed production and comparison by region in 2019 [2].

Countries/Region	Total Seaweed Production (Farmed and Wild)		Seaweed Cultivation	
	Tonnes (Wet wt.)	Share of World Production (%)	Tonnes (Wet wt.)	Share in Farmed and Wild Production (%)
World	**35,762,504**	**100.00**	**34,679,134**	**96.97**
Asia	**34,826,750**	**97.38**	**34,513,223**	**99.10**
1. China	20,296,592	56.75	20,122,142	99.14
2. Indonesia	20,296,592	56.75	20,122,142	99.14
3. Republic of Korea	1,821,475	5.09	1,812,765	99.52
4. Philippines	1,500,326	4.20	1,499,961	99.98
5. DPR of Korea	603,000	1.69	603,000	100.00
7. Japan	412,300	1.15	345,500	83.80
8. Malaysia	188,110	0.53	188,110	100.00
America	**487,241**	**1.36**	**22,856**	**4.69**
6. Chile	426,605	1.19	21,679	5.08
Europe	**287,033**	**0.80**	**11,125**	**3.88**
9. Norway	163,197	0.46	117	0.07
Africa	**144,909**	**0.41**	**117,791**	**81.29**
10. United Republic of Tanzania	106,069	0.30	106,069	100.00
Oceania	**16,572**	**0.05**	**14,140**	**85.32**

Data from FAO Fishery and Aquaculture Statistics. Global Aquaculture Production 1950–2019 (FishStatJ).

Due to their grape-like appearance, they are commonly known as sea grapes or sea caviars. They are also known by different names in certain countries; most names directly translating the term “sea grape” into their vernacular. For instance, “nama” in Fiji, “bulung boni” in Indonesia, “umi budo” (海ぶどう) or “kumejima” in Japan, “bada podo” (바다 포도) in Korea, “lato”, “lelato”, or “ararosip” in the Philippines, “latok” in Malaysia, and “rong nho” or “rong nho biển” in Vietnam [7][8][9][10][11]. They usually inhabit sandy or muddy shallow sea bottoms [12]. *C. lentillifera* J. Agardh was originally described from the Red Sea coast [13]. It has been reported to be widely distributed in subtropical and tropical locations, such as the South China Sea, Southeast Asia, Japan, Taiwan, and Oceania, where it is directly consumed as a snack, in salads, and sushi, or in its salt-preserved form [14]. It has been described to have a salty taste and succulent texture. **Figure 1** illustrates fresh *C. lentillifera*.

Figure 1. Fresh *C. lentillifera*.

C. lentillifera is an alternative food that can also be used therapeutically. Over the years, it has gained popularity owing to its nutritional value, potential pharmacological benefits, and sustainability [15][16]). Within the past five years, several publications have reviewed various aspects of *Caulerpa* spp., such as its consumption, nutritional value, and farming [6], bioactive components and biotechnological applications [17], metabolite roles in cancer treatments [18], as well as its position as a functional food [11]. Only two publications had focused on reviewing the green algae genus *Caulerpa* in chemical composition, diversity, ecology, farming, pharmacological and industrial potential [10][19]). However, the review did not critically evaluate *C. lentillifera* specifically. To the best of researchers' knowledge, no publication has focused solely on *C. lentillifera* in terms of its nutrient content and recent advances in potential health benefits that would make it suitable for pharmaceutical and nutraceutical use.

2. Nutritional Value of *C. lentillifera*

The proximate composition and the total dietary fibre content of *C. lentillifera* from different countries are shown in **Table 2**.

Table 2. Proximate composition and fibre contents of *C. lentillifera* from different countries.

	China	Indonesia	Malaysia	Philippines	Taiwan	Thailand	USA	Vietnam	Reference
Water content, % [a]	95.09–95.95	77.57–95.01	87.05–92.3	90.1–91.7	94.28	95.4–95.8	94	-	[20] [21] [22] [23] [24] [25] [26] [27]

China	Indonesia	Malaysia	Philippines	Taiwan	Thailand	USA	Vietnam	Reference	
									[28] [29] [30] [31] [32] [33]
Ash, % dw	25.31–55.20	1.02–3.41	2.1–29.61	4.17–26.57	1.27–22.2	24.21–57.01	46.4	-	[20] [21] [22] [23] [33] [34] [35] [36]
Moisture, %[b]	12.91–13.66	-	-	-	6.42	25.31		16	[33] [36] [37]
Carbohydrate, % dw	21.32–50.71	0.36–17.08	44.02–72.9	61.82	3.67–69.75	59.27	11.8	44	[20] [22] [23] [24] [25] [26] [27] [29] [30] [31] [32] [33] [34] [35] [36] [37]
Protein, % dw	12.5–14.76	0.43–3.84	13.24–19.38	0.78–5.1	0.53–10.5	4.67–12.49	9.7	4.89–7.0	[20] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [33] [34]

	China	Indonesia	Malaysia	Philippines	Taiwan	Thailand	USA	Vietnam	Reference
									[35] [36] [37]
Lipid, % dw	0.78–2.32	0.32–0.79	0.7–2.87	0.05–0.75	0.09–1.57	0.86–2.0	7.2	1.2–14.0	[20] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [33] [34] [35] [36] [37]
Fibre, % dw	7.81–12.98	14.38	4.12–19.4	-	0.17–2.97	-	-		[23] [24] [25] [26] [27] [29] [32] [33]
Total dietary fibre, g/100 g	33.44–37.16	-	32.99	30.67	-	-		17.5	[25] [33] [34] [36] [37]
Insoluble fibre	26.56–28.98	-	15.78	27.17	-	-	-	16.6	[31] [32] [33] [36] [37]
Soluble fibre	2.45–8.6	-	17.21	3.5	-	-	-	2.6–4.21	[24] [33] [34] [35] [36] [37]

^{a} Wet weight; ^{b} Dry weight

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ther non-carbohydrate components such as polyphenols, resistant proteins, saponins, and waxes may also be present [38]. However, these may vary even within its species [39]. For instance, although belonging to the same genus and family, *C. lentillifera* has higher carbohydrate content than *C. racemosa* [40]. *C. lentillifera* contains as low as 0.36% and as high as 72.9% carbohydrates in its dry matter (**Table 2**). Its dietary fibre content is approximately 17.5 to 36.7% in 100 g dried *C. lentillifera,* respectively. Water-soluble fibre content is approximately 2.45–17.21%. Water-soluble fibres are usually higher in red algae, around 15 to 22% in the dry matter, such as in *Chondrus crispus* (Irish moss) and *Porphyra/Pyropia* spp. (nori) [41][42].

In seaweed, soluble fibres can absorb water up to 20 times its volume [43]. This helps enhance the binding of water with food pellets in the gut and aids in stool bulking and shortening transit time in the colon; these act as positive factors that may prevent colon cancer [44]. In *Caulerpa* spp., soluble polysaccharides mostly consist of glucans and sulfated polysaccharides [19]. Sulfated polysaccharides from *C. lentillifera* have been reported to have physiological benefits, which will be discussed in the latter part of this research. Insoluble dietary fibres are generally not digested in the human gastrointestinal tract. Upon contact with water, they do not form gels but retain water in their structural matrix, increasing faecal bulk and accelerated intestinal transit [45]. Insoluble dietary fibres of *C. lentillifera* range from 15.75 to 28.98% (**Table 2**). However, *C. lentillifera* has lower dietary fibre content than other green seaweeds, such as *C. racemosa* and *Ulva reticulata,* at 65.7% and 64.9%, respectively [40][46][47]. In adults, high consumption of dietary fibre, particularly fermentable fibres, has been linked with increased short-chain fatty acid (SCFA) contents in the stool [44][48].

2.2. Protein and Amino Acids

With increased population growth and demand for protein, seaweeds are plausibly viable and sustainable protein sources due to their low environmental impact and fast-growing rate. Furthermore, the protein content of whole algae is very high compared to common food staples such as cereals, legumes, and nuts [49]. With its versatility and simplicity of usage, whole algal protein has the potential to be a tremendous whole-food protein source, as well as a great way to supplement protein-deficient diets [50]. When comparing the protein contents, the levels of proteins are higher in Rhodophyta (red), followed by Chlorophyta (green), and Ochrophyta (brown) [51][52]. The protein content of *C. lentillifera* ranged from 0.43 to 19.38% in various countries (**Table 2**). The wide difference and instability of the protein content could be affected by various external factors, such as water temperature, season, geography, weather, and other factors [46]. It was reported that protein content in seaweed was higher in winter than in autumn and summer [53][54].

The protein quality depends on the presence and quantity of essential amino acids. Amino acids are the building blocks that form proteins bound together via peptide bonds formed between the carboxyl group of an amino acid and the amino group of the next amino acid in line [55]. *C. lentillifera* are considered to have high-quality proteins as the essential amino acids present and were close to egg and soya protein content [54]. Except for tryptophan, almost all essential amino acids (EAA) are present. Their amino acid profile is dominated mainly by leucine, valine, aspartic acid, glutamic acid, and glycine. The major amino acids in seaweed proteins are aspartic and glutamic acid, which contribute to the umami flavour [56]. The amino acid profile of *C. lentillifera* is shown in **Table 3**.

Table 3. Amino acid profile of *C. lentillifera*.

Amino Acids	g/100 g Sample	Mean ± SD	Reference

Essential amino acids	g/100 g		[31][32][33]
Threonine	0.79–9.3	4.94 ± 3.49	
Valine	0.87–11.16	5.66 ± 4.09	
Lysine	0.68–7.78	4.59 ± 3.16	
Histidine	0.08–2.07	0.98 ± 0.81	
Isoleucine	0.62–6.94	3.71 ± 2.57	
Leucine	0.99–12.86	6.51 ± 4.68	
Methionine	0.18–2.37	1.45 ± 0.93	
Phenylalanine	0.61–6.6	3.57± 2.38	
Total EAA	4.7–57.01	29.86 ± 21.10	
Non-essential amino acids			
Aspartic acid	1.43–14.89	8.37 ± 5.74	
Serine	0.76–9.47	5.00 ± 3.60	
Cysteine	0.81–1.2	1.03 ± 0.18	
Glutamic acid	1.77–14.72	9.30 ± 6.15	
Glycine	0.64–19.23	9.17 ± 8.14	
Arginine	0.83–6.21	3.86 ± 2.56	
Alanine	0.85–13.36	6.57 ± 5.07	
Tyrosine	0.48–4.74	2.65 ± 1.78	
Proline	0.57–5.75	3.43 ± 2.34	
Total NEAA	7.67–90.0	49.67 ± 35.45	
Total amino acids	12.37–147.0	63.84 ± 59.40	
EAA/NEAA	0.61–0.63: 1		

2.3. Minerals

Minerals absent from freshwater algae and terrestrial crops are mostly available in seaweeds [57]. Minerals are essential and required in certain amounts for the normal metabolic functioning of the human body [58]. The mineral element found present in *C. lentillifera*, including essential minerals and toxic minerals, are presented in **Table 4**. The mineral content varies due to the phylum or class of the seaweed and geographical origin, along with seasonal, environmental, and physiological variations [39].

Table 4. Mineral element composition in *C. lentillifera* in different countries.

Countries	Australia	China	Malaysia	Philippines	Thailand	USA	Vietnam	Reference
Element								
Aluminium, Al	-	8.57	-	-	-	-	744	[32][36]
Antimony, Sb	-	3.25–4.18	-	-	-	-	-	[32]
Arsenic, As	1.06 µg/g	5.14–6.46	-	-	-	-	≤1	[21][32][36]
Barium, Ba	-	0.26–1.71	-	-	-	-	4.75	[32][36]
Beryllium, Be	-	0.38–1.71	-	-	-	-	-	[32]
Boron, B	18.4 µg/g	2.37–2.58	-	-	-	70 µg/g	21.7	[20][21][32][36]
Cadmium, Cd	0.53 µg/g	0.36–0.7	-	-	-	-	1.14	[21][32][36]
Calcium, Ca	16,650 µg/g	0.77–3728.35	32.7–118.66	988.44	780	0.0095	8137	[20][21][22][23][32][33][35][59]
Cerium, Ce	-	0.83–1.04	-	-	-	-	-	[32]
Chromium, Cr	-	0.23–0.34	-	-	-	-	3.3	[32][36]
Cobalt, Co	-	0.03–0.07	-	-	-	-	1.35	[32][36]
Copper, Cu	0.89 µg/g	3.04–20.37	1.18–3.0	-	2200 µg/g	1 µg/g	2.74	[20][21][22][23][32][33][36][59]
Gallium, Ga	-	0.11–0.15	-	-	-	-	-	[32]
Iodine, I	-	0.73–26.3	4.78 µg/g	-	1424 µg/g	-	-	[24][32]
Iron, Fe	-	13.62–1972.97	145.0	430.93	9.3	167 µg/g	595	[20][23][32][33][35][36]

Countries	Australia	China	Malaysia	Philippines	Thailand	USA	Vietnam	Reference
Lithium, Li	-	0.28–2.15	-	-	-	-	-	[32]
Magnesium, Mg	5.875 mg/g	1.93–8126.59	78.33–170.0	-	630	0.0165	10,663	[21][23][32][33][36][59]
Manganese, Mn	-	5.54–1341.07	-	-	7.9	10 µg/g	425	[20][32][33][36]
Molybdenum, Mo	-	0.02–0.05	-	-	-	-	1.32	[32][36]
Nickel, Ni	-	-	-	-	-	-	1.88	[36]
Nitrogen, N	-	0.18–1.10	-	-	-	0.0239	-	[20][32]
Phosphorus, P	-	-	11.22–25.40	-	1030	0.0016	1073	[20][23][33][36][59]
Lead, Pb	0.16 µg/g	-	-	-	-	-	-	[21]
Potassium, K	-	0.91–4967.34	66.16–1413.0	-	970	0.007	1066	[20][23][32][33][36][59]
Rubidium, Rb	-	2.24–2.57	-	-	-	-	-	[32]
Selenium, Se	3.9 µg/g	0.02–0.05	-	-	-	-	≤1	[21][32][39]
Sodium, Na	-	14.90–9432.33	933.83–12,297.0	-	-	-	130,794	[23][32][36][59]
Strontium, Sr	143 µg/g	10.19–11.31	-	-	-	-	104	[21][32][36]
Sulphur, S	-	-	-	-	-	0.0155	6733	[36]
Tin, Sn	-	0.021–0.024	-	-	-	-	-	[32]
Titanium, Ti	-	0.07–0.16	-	-	-	-	-	[32]
Vanadium, V	0.44 µg/g	0.07–0.32	-	-	-	-	2.46	[21][32][36]
Zinc, Zn	27.55 µg/g	1.89–33.90	0.14–6.2	1.09	2.6	17 µg/g	15.2	[20][21][23][32][33][35]

[60][61]. On

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detrimental effects, which are present in *C. lentillifera* [62][63]. As stated in **Table 4**, Na, Mg, K, Ca, and Mn has a wide range of concentrations, among all mineral elements, with the highest concentration in Na (14.90–130,794 mg/100 g). For Mg, the highest concentration value was around 8126.59 mg/100 g (in China) to 10,663 mg/100 g

Countries	Australia	China	Malaysia	Philippines	Thailand	USA	Vietnam	Reference
								[36][59]

4 mg/100

All values are presented in mg/100 g sample unless stated otherwise.

The calcium content in *C. lentillifera* is comparable to common foods such as milk products, meat, fish, poultry, and legumes. For instance, the highest concentration value found in *C. lentillifera* was 8137 mg/100 g (in Vietnam) which is 4 times higher than the calcium content in high calcium milk powder, 2000 mg/100 g [64][65]. Iodine and iron are important to the human diet, both of which can be found in high concentrations in seaweeds, including *C. lentillifera* [66]. Insufficiency and deficiency of iodine could lead to goiter and hypothyroidism [65]. Although the iodine content in *C. lentillifera* is relatively low compared to in other green seaweed such as *Ulva clathrata* [67], it can be considered a cheap and reasonable option to fulfil the minimum iodine required needed by the body [65][68].

The deficiency of iron is a major health problem worldwide. The root of this problem is caused by prolonged inadequate intake due to low bioavailability in the diet. Especially during the period of growth and chronic blood loss, the increase in iron requirement may also cause iron deficiency [65]. The consumption of *C. lentillifera* could be a potential iron supplement to combat iron deficiency. However, it is difficult to generalise or conclude whether the mineral contents in *C. lentillifera* is high or low, as different sampling region have greatly varied environmental conditions [19]. From the compiled data in **Table 4**, it can be concluded *C. lentillifera* are rich in minerals that meet the requirement of the human body. However, the Na/K ratios need careful consideration, as it has been reported to be higher than in other seaweeds such as *Sargassum polycystum* and *Eucheuma cottonii* [24]. If the Na/K ratio is too high, it is detrimental to the sodium to potassium balance in the human body, which can result in cardiovascular diseases. A simple desalting operation, such as soaking, is recommended before eating [32].

2.4. Lipids

C. lentillifera are significantly low in lipid content ranging from 0.05 to 14.0% in dry weight. Despite low lipid composition, *C. lentillifera* has raised interest due to a high content of long-chain polyunsaturated fatty acids (PUFAs) and carotenoids [19][41]. Compared to terrestrial vegetables, *C. lentillifera* contain significantly higher levels of polyunsaturated fatty acids, which act as strong antioxidants, such as ω-3 and ω-6 [69], which have various roles in the prevention of cardiovascular diseases, osteoarthritis, and diabetes [70]. The fatty acids profile of *C. lentillifera* are shown in **Table 5**. The ω-3 and ω-6 PUFAs, particularly linoleic acid (18:2ω6) and α-linolenic acid (18:3ω3), cannot be synthesised by most heterotrophic organisms and can only be obtained through dietary intake [32][71]. All these PUFAs can be found in *C. lentillifera*, with α-linolenic acid (18:3ω3) being the most abundant [71]. The fatty acid compositions of *C. lentillifera* are as tabulated in **Table 5**.

Table 5. Fatty acids composition in *C. lentillifera*.

Fatty Acids, %		Reference
Saturated fatty acids		
C 3:0	15.92	[35]

Fatty Acids, %	Reference	
C 4:0	2.3	[26]
C 6:0	0.002–0.3	[26][30][32]
C 8:0	0.0004–1.1	
C 10:0	0.0001–6.4	[24][26][30][32]
C 11:0	0.85–1.1	[24][26][32]
C 12:0	0.006–0.69	[24][26][30][32]
C 13:0	0.001–1.54	[24][26][30][32]
C 14:0	0.019–2.92	[24][26][30][32]
C 15:0	0.001–2.1	[24][26][30][32]
C 16:0	0.22–49.46	[24][26][30][33]
C 17:0	0.0001–3.36	[24][26][30][32]
C 18:0	0.012–7.83	[24][26][30][33]
C 20:0	0.001–1.98	[24][26][30][33]
C 21:0	0.001–1.62	[24][26][30][32]
C 22:0	0.005–1.15	[24][26][30][33]
C 23:0	0.01–2.05	[24][26][30][32]
C 24:0	0.041–8.85	[24][26][30][32]
Monounsaturated fatty acids		
C 14:1	0.001–1.5	[24][26][30][32]
C 14:1 ω-9	0.59	[31]
C 15:1	0.83–2.54	[26][31][32]
C 16:1 ω-9	0.029–8.24	[33]
C 17:1	0.0003–2.67	[24][26][32]
C 18:1 ω-9c	0.03–32.49	[24][26][30][32]
C 18:1 ω-9t	0.22–0.93	[24][26][30][32]

Fatty Acids, %	Reference	
C 20:1	0.18–1.69	[26][33]
C 20:1 ω-9	0.009–0.17	[24]
C 22:1 ω-9	0.0001–2.8	[24][26][33]
C 24:1 ω-7	0.1–2.79	[26][32]
C 24:1 ω-9	0.66–0.93	[24][30]
Polyunsaturated fatty acids		
n-6 PUFA		
C 18:2 (ω6c)	0.48–13.14	[30][32]
C 18:2 (ω6t)	0.09–4.13	[33]
C 18:3 (ω6)	0.002–13.89	[24][33]
C 20:2 (ω6)	0.002–4.27	[24][30]
C 20:3 (ω6)	0.001–3.3	[32]
C 20:4 (ω6)	0.003–6.7	[33]
C 22:2 (ω6)	0.95–1.56	[30]
C 22:6 (ω6)	0.11–0.83	[32][33]
n-3 PUFA		
C 18:3 (ω3)	0.035–13.30	[24][32]
C 20:3 (ω3)	0.001–2.72	[24][32]
C 20:5 (ω3)	0.003–1.91	[24][33]
C 22:6 (ω3)	0.003–3.64	[24][30][33]

ements of 100 g of [72][73] ily UL for comparison purposes.

Table 6. Vitamin content in *C. lentillifera*, the daily recommended nutrient intake (RNI), and the tolerable upper intake level (U.L.) per day.

Vitamins	Present in *C. lentillifera*	RNI/Day ^{1}	UL/day ^{2}	Reference
Thiamine (Vitamin B1), mg/100 g	0.021–8.8	1.1–1.2 mg	ND	[22][23]
Riboflavin (Vitamin B2), mg/100 g	0.02–2.5	1.1–1.3 mg	ND	
Vitamin B3 (as niacin), mg/100 g	1.09–200	14–16 mg	35 mg NE	

Vitamins	Present in *C. lentillifera*	RNI/Day ^{1}	UL/day ^{2}	Reference
		NE		
Vitamin C, mg/100 g	0.028–274	70 mg	2000 mg	[8][22][24][32][33]
Vitamin E, mg α-tocopherol/g	0.02–0.46	7.5–10 mg	1000 mg	[24][32][33]
Vitamin A (as β-carotene), µg RE/g	0.1–1530	600 µg RE	3000 µg RE	[8][20][21][22][23][24]

[1] The values of RNI per day are for adults aged 19–65. [2] RNI and tolerable upper intake levels are obtained from Recommended Nutrient Intakes for Malaysia (Ministry of Health, 2017).

roperties, with concentrations ranging from 0.028–274 mg/100 g. Among other seaweed groups, *C. lentillifera* is generally rich in B group vitamins [74]. Vitamin B1, B2, and B3 were present in *C. lentillifera* in trace amounts; however, the amount detected still exceeded the recommended daily intake. The total amount of vitamin B2 in *C. lentillifera* is considerably higher than in various legumes, including chickpeas, lentils, red and black grain, and soya beans, which contain relatively high riboflavin levels of around 0.2–0.5 mg/100 g [64]. Recent data on the riboflavin content of selected commercial rice, such as fragrant rice, basmati rice, and Siam rice, showed that all varieties contain 0.06 mg riboflavin per 100 g [75]. The amount of B3 in *C. lentillifera*, 1.9–200 mg/100 g, was also higher than that of *Ulva fasciata*, 1.02 mg/100 g, and *E. flexuosa*, 0.98 mg/100 g [76].

2.6. Pigments

The most abundant pigments in the *Caulerpa* species are chlorophylls, mostly composed of chlorophyll a and b [77]. Chlorophylls have an antioxidant property that makes them useful nutritional and a health supplement [78]. Chlorophylls available in our diet are obtained via the consumption of green vegetables. Several studies have demonstrated that chlorophylls and their degradation products have anti-proliferative and anticancer properties [41][79]. Carotenoids which are tetraterpenoid pigments are also found in *C. lentillifera*. Most carotenoids were present in seaweeds, such as α- and β-Carotene, lutein, and zeaxanthin, in which all except α-carotene were detected in *C. lentillifera*, as shown in **Table 7**.

Table 7. The concentration of pigments found in *Caulerpa lentillifera*.

Pigments	Concentration (mg/100 g)	Reference
Chlorophylls	0.729–82.32	[22][37][80]
Chlorophyll a	0.332–53.0	
Chlorophyll b	0.397–118.0	
Carotenoids	2.578–22.0	[22][80]
Astaxanthin	3.0	[77]
β-Carotene/Lycopene	0.1–1530.0 µg RE/g	[20][21][24][77][80]
Caulerpin	25.79–33.59 µg/g	[37]

Pigments	Concentration (mg/100 g)	Reference
β-Cryptoxanthin	1.3	[77]
Canthaxanthin	14.6	
Fucoxanthin	<0.001	
Lutein	<0.02–2.113	[77][80]
Violaxanthin	0.893	[80]
Zeaxanthin	0.213–3.6	[77][80]

em, good skin, and eye health [78]. β-carotene also has antioxidant properties that protect the body from free radicals produced by oxidation of other molecules [81]. Carotenoids like lutein and zeaxanthin prevent the progress of age-related macular degeneration [56][82]. Caulerpin is a bis-indole alkaloid found in genus *Caulerpa* [83]. In *C. lentillifera*, it is found present at concentrations of 25.79–33.59 µg/g. This compound contributes to some of its reported therapeutic activities. For instance, caulerpin isolated from *Caulerpa taxifolia* showed anti-diabetic properties [84], whereas caulerpin sourced from other *Caulerpa* spp. demonstrated potential anti-inflammatory and anti-nociceptive properties [85].

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