Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(3): 1495 – 1508 (2025)
www.ejabf.journals.ekb.eg

Amino Acid and Fatty Acid Profiles of Green Seaweeds in Kepulauan Riau

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ARTICLE INFO

Article History:
Received: Feb. 9, 2025
Accepted: May 6, 2025
Online: May 27, 2025

Keywords:
Amino acid,
Fatty acid,
Green seaweed

ABSTRACT

Green seaweeds are crucial part of the aquatic ecosystem in Indonesia, especially in the Kepulauan Riau Province. This research aimed to analyze the amino acid and fatty acid profiles of green seaweeds from Natuna and Tanjungpinang waters to explore their potential as functional food ingredients. The study focused on species such as *Caulerpa taxifolia*, *Caulerpa microphysa*, *Caulerpa racemosa*, *Caulerpa lentillifera*, and *Codium* sp. The seaweeds were collected, washed with seawater, sun-dried for three days, and ground into powder. The analysis revealed that species variations affect amino acid composition, identifying eight essential amino acids and seven non-essential amino acids, with glutamic acid being the most abundant. Additionally, 18 fatty acids were identified, with high levels of SPA, MUFA, PUFA, omega-3, and omega-6 fatty acids across all species. These green seaweeds showed significant potential as a raw material for functional food development.

INTRODUCTION

Green seaweeds (*Chlorophyta*) have been an important component of traditional diets in many countries, especially Asia. In addition to their culinary applications, green seaweeds are rich in nutrients and bioactive compounds, making them an interesting topic in nutrition and health studies. Research by **Sanjaya *et al*. (2017**) showed that the differences in fresh, semi-dry, and dry treatments of green seaweed *C. racemosa* did not affect the nutritional content including carbohydrates, fat, protein, ash, and fiber. The highest mineral content is potassium. Fatty acids in *C. racemosa* are dominated by palmitic acid, linoleic acid, α-linoleic acid, arachidonic acid, and oleic acid. The highest amino acid content is glutamic acid. The highest antioxidant activity and total phenol content of *C. racemosa* extract were obtained from the dry sample, while the highest flavonoid content was in the semi-dry *C. racemosa* extract. Fractionation of the dry *C. racemosa* extract sample obtained three fractions, namely the n-hexane, ethyl acetate, and methanol/water fractions. The ethyl acetate fraction is the fraction that has the highest antioxidant activity and reducing power.

One quite interesting species is *Caulerpa lentillifera*, known as "sea grapes" due to its shape, resembling grape grain clusters. This species is a popular food in Southeast Asia and has garnered significant interest from researchers due to its high nutritional content. *Caulerpa lentillifera* is recognized for its high fiber content, protein, minerals, and bioactive compounds, which offer numerous health benefits.

Essential amino acids are crucial components the human body cannot synthesize, necessitating their acquisition through dietary sources. A study by **Iskandar *et al*. (2023)** showed that *Caulerpa lentillifera* cultivated under controlled conditions contains essential amino acids such as histidine, threonine, valine, lysine, isoleucine, and leucine. Similarly, **Zhang *et al*. (2020)** found that *Caulerpa lentillifera* from various regions exhibits a significant concentration of essential amino acids, including phenylalanine, isoleucine, valine, arginine, lysine, leucine, threonine, and histidine.

Alongside amino acids, the fatty acid profile of green seaweeds has garnered attention due to its implications for human health. A study by **Zhang *et al*. (2023)** demonstrated that *Caulerpa lentillifera* cultivated in various regions is rich in unsaturated fatty acids, including omega-3 and omega-6 fatty acids, which contribute to reducing cardiovascular disease risk and support heart health and brain function. Additionally, research by **Abd Halim *et al*. (2019)** identified the presence of beneficial fatty acids such as palmitic acid and oleic acid in *Caulerpa lentillifera*, further underscoring its nutritional value.

The chemical composition of green seaweeds, such as *Caulerpa lentillifera*, is influenced by geographical location, environmental conditions, and cultivation techniques. **Rodrigues *et al*. (2015)** indicated that environmental factors, including salinity, temperature, and nutrient availability in aquatic systems, can influence the nutrient composition of green seaweeds. This indicates the importance of further research to explore the factors influencing the nutrient composition of *Caulerpa lentillifera* across different ecosystems.

In addition to its nutritional content, *Caulerpa lentillifera* may serve as a source of bioactive compounds exhibiting biological activity. **Pangestuti and Kim (2015)** assert that seaweed is rich in bioactive compounds that can improve the umami flavor in food products, enhance overall taste, and offer supplementary health benefits. This presents significant opportunities for developing green seaweed-based products within the functional food sector, such as *Caulerpa lentillifera*.

Numerous studies indicate that *Caulerpa lentillifera* exhibits significant potential as a source of nutrients and bioactive compounds beneficial to human health. However, further research is necessary to identify factors influencing its nutritional composition and explore the mechanisms underlying its various health benefits. This research focused on analyzing the amino acid and fatty acid profiles of green seaweeds found in the waters of

Natuna and Tanjungpinang, highlighting their potential as ingredients for functional foods.

MATERIALS AND METHODS

This study utilized samples of *Caulerpa taxifolia*, *Caulerpa microphysa*, *Caulerpa racemose* and *Caulerpa lentillifera* collected from various sampling locations in the Natuna waters and *Codium* sp., in the Tanjungpinang of Kepulauan Riau Province. The samples were then analyzed to determine their amino acid and fatty acid profiles using Ultra High-Performance Liquid Chromatography (UPLC) **(Waters, 2012)** and Gas Chromatography-Flame methods.

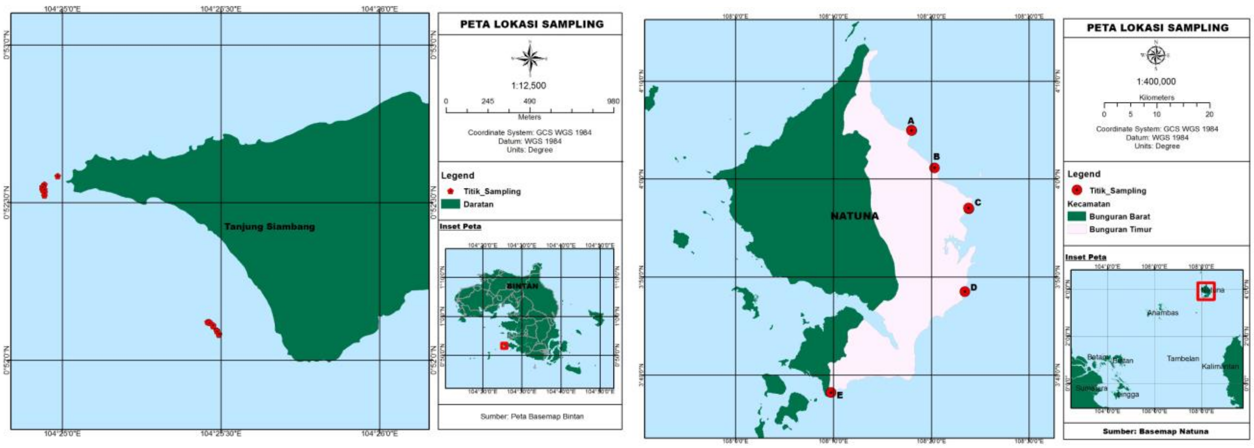


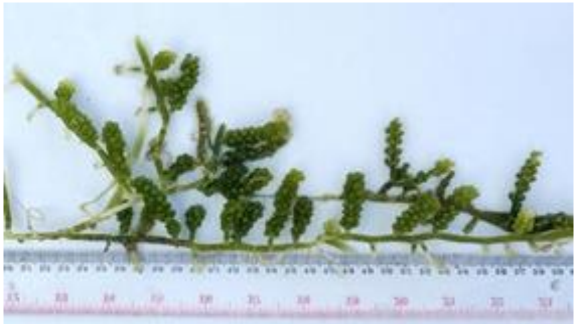
Fig. 1. Seaweed sampling location

Seaweeds preparation

The initial phase involved rinsing the seaweed with seawater to eliminate impurities. Subsequently, the seaweed was dried for three days under the sunlight. Upon reduction of the sample's water content, it underwent size reduction and refinement into a fine powder. The green seaweeds specimens that we used in this study can be seen in the following image.

C. taxifolia

C. microphysa



C. racemose

C. lentillifera

Codium sp

Fig. 2. Green seaweeds specimens

Amino acid analysis

The analysis of amino acids was conducted using the Ultra Performance UPLC method. The amino acid testing procedure began with weighing the sample and adding 10mL of 6 N HCl solution. The sample given HCl solution was then heated using an oven at 100°C for 24 hours. The sample was taken when the temperature was cold and filtered to remove the residue. A volume of 25 µl of the sample was transferred into a test tube and combined with a drying solution. The drying solution was a mixture of methanol, sodium acetate, and triethylamine (TEA) with a 2:2:1 ratio. The sample was then dried using a vacuum. The dried sample was treated with 25µL of derivatization solution and was allowed to stand at room temperature for 20 minutes. The derivatization solution was a mixture of methanol, PITC (picotiocyanate), and triethylamine with a ratio of 1:1:2. Prior to injection into the HPLC, samples were supplemented with 25µL of 1 M sodium acetate buffer.

Fatty acid analysis

Before fatty acid analysis, the extraction of fat/oil from the sample material was performed using the Soxhlet method. The extracted oil/fat was subsequently tested at 20-30mg. The stages of fatty acid analysis began with hydrolyzing the fat/oil in the sample into fatty acids followed by transforming into its more volatile ester form. The transformation was carried out by methylation to obtain fat methyl ester (FAME). FAME was then analyzed using a gas chromatograph. Each component was identified by comparing its retention time with the standard under the same analysis conditions. The retention time was calculated on recorder paper as the distance from the line when the solvent peak appeared to the middle of the peak of the component, being considered using a Gas Chromatography-Flame Ionization Detector (GC-FID) device.

Data analysis

The study's experimental design used a completely randomized design (CRD) with one factor, namely the difference in green seaweed species. Amino acid and fatty acid profile data were analyzed using the One-way ANOVA with two replications each. Significant data ($P<0.05$) were further tested by Duncan. Data were processed using the Statistical Package for the Social Sciences (SPSS) version 29 software.

RESULTS

Amino acid profile

Table (1) presents the amino acid profile of green seaweeds sourced from the waters of Tanjungpinang and Natuna. The analysis indicates that variations among species influence the essential and non-essential amino acid profiles, total essential and non-essential amino acids, and total amino acids overall ($P< 0.05$) of green seaweed.

The essential amino acids phenylalanine, isoleucine, valine, leucine, threonine, and histide significantly differed between species ($P< 0.05$). The amino acid arginine of *C. lentillifera* and *Codium* sp. was not significantly different ($P> 0.05$), but other species were significantly different ($P< 0.05$). The amino acid lysine of *C. racemosa* and *C. lentillifera* was not significantly different ($P> 0.05$), but other species were significantly different ($P< 0.05$). The total essential amino acids were the highest in *C. taxifolia* and the lowest in *C. lentillifera*. The non-essential amino acid profiles of serine, glutamic acid, glycine, aspartic acid, tyrosine, and proline significantly differed between species ($P< 0.05$). The amino acid alanine of *C. microphysa* and *C. racemosa* was not significantly different ($P> 0.05$), but other species were significantly different ($P< 0.05$). The total non-essential amino acids and total overall amino acids were the highest in the species *C. taxifolia* and the lowest in *C. lentillifera*.

Leucine was the highest essential amino acid in *C. taxifolia* and *C. microphysa*, phenylalanine in *C. racemosa*, arginine in *C. lentillifera*, and threonine in *Codium* sp.. Lysine was the lowest essential amino acid in *C. taxifolia*, *C. microphysa*, and *C. racemosa*, isoleucine in *C. lentillifera*, and histidine in *Codium* sp. The highest non-essential amino acid for all species was glutamic acid, and the lowest was tyrosine.

Table 1. Amino acid profile of green seaweed from Kepulauan Riau seawaters

Amino acid (%)	*C. taxifolia**	*C. microphysa**	*C. racemose**	*C. lentillifera**	*Codium* sp**.
Essential amino acids					
Phenylalanine	0.751±0.006[a]	0.531±0.001[b]	0.817±0.003[c]	0.122±0.021[d]	0.383±0.001[e]
Isoleucine	0.577±0.002[a]	0.361±0.001[b]	0.458±0.001[c]	0.073±0.013[d]	0.239±0.000[e]
Valin	0.763±0.004[a]	0.471±0.001[b]	0.610±0.002[c]	0.141±0.018[d]	0.342±0.002[e]
Arginine	0.647±0.003[a]	0.449±0.002[b]	0.630±0.002[c]	0.200±0.020[d]	0.290±0.001[d]
Lysine	0.234±0.001[a]	0.225±0.000[b]	0.208±0.000[c]	0.155±0.011[c]	0.264±0.000[d]
Leucine	0.961±0.003[a]	0.577±0.001[b]	0.770±0.005[c]	0.174±0.036[d]	0.387±0.002[e]
Threonine	0.824±0.003[a]	0.548±0.001[b]	0.748±0.003[c]	0.109±0.021[d]	0.421±0.002[e]
Histidine	0.190±0.004[a]	0.062±0.000[b]	0.163±0.002[c]	n/a	0.096±0.002[d]
Total essential amino acids	4.949±0.030[a]	3.225±0.007[b]	4.406±0.115[c]	0.975±0.044[d]	2.422±0.005[e]
Non-essential amino acids					
Serine	0.977±0.003[a]	0.494±0.002[b]	0.810±0.001[c]	0.230±0.032[d]	0.568±0.001[e]
Glutamic acid	1.199±0.004[a]	0.731±0.006[b]	1.002±0.002[c]	0.406±0.040[d]	0.610±0.002[e]
Alanine	0.737±0.003[a]	0.411±0.002[b]	0.577±0.002[b]	0.243±0.027[c]	0.399±0.001[d]
Glycine	0.775±0.003[a]	0.565±0.001[b]	0.902±0.004[c]	0.297±0.016[d]	0.468±0.002[e]
Aspartic acid	0.960±0.005[a]	0.608±0.002[b]	0.810±0.004[c]	0.366±0.026[d]	0.521±0.000[e]
Tyrosine	0.411±0.004[a]	0.271±0.002[b]	0.434±0.001[c]	0.094±0.000[d]	0.248±0.001[e]
Proline	0.522±0.003[a]	0.318±0.003[b]	0.436±0.001[c]	0.141±0.014[d]	0.261±0.002[e]
Total non-essential amino acids	5.583±0.018[a]	3.401±0.020[b]	4.976±0.013[c]	1.778±0.074[d]	3.076±0.003[e]
Total amino acids	10.533±0.056[a]	6.626±0.027[b]	9.382±0.024[c]	2.754±0.118[d]	5.499±0.008[e]

Superscript font different rows showed a significant difference ($P<0.05$). Values are means of two replicates ± standard deviations SD. n/a (not available).

Fatty acid profile

The fatty acid profile of green seaweeds sourced from the waters of Tanjungpinang and Natuna is detailed in Table (2). The analysis conducted through gas chromatography revealed that the fatty acid composition of green seaweed is categorized into three primary groups: saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids (PUFA). The identification results showed that the five species of green seaweed contained 18 distinct types of fatty acids

The total SFA content was the highest in all analyzed green seaweed species. The highest SFA content was found in *C. taxifolia* (1.414±0.010%). Meanwhile, the MUFA content was the lowest in all analyzed green seaweed species. The highest MUFA content was found in *Codium* sp. (0.272±0.003%). The PUFA content in the analyzed seaweed species was lower than SFA. The highest MUFA content was found in *C. taxifolia* (0.383±0.003%).

Palmitic acid (C16:0) was identified as the predominant SFA in *C. Lentifera* (1.084±0.504%). At the same time, capric acid (C10:0) in *C. Lentifera* was the least dominant SFA of all species, with the lowest content (0.004±0.002%). Oleic acid (C18:1n9c) was the predominant MUFA across all species, exhibiting the highest concentration in *Codium* sp. at 0.209±0.003%. In contrast, myristoleic acid (C14:1) in *C. Lentifera* displayed a comparatively low concentration of 0.011±0.004%. Linolenic acid (C18:3n3) was the predominant PUFA across all species, exhibiting the highest concentration in *C. Lentifera* at 0.159±0.019%. EPA (C20:5n3) exhibited the lowest dominance, particularly in *Codium* sp. (0.010±0.000).

Table 2. Fatty acids profile of green seaweed from Kepulauan Riau Seawaters

Asam lemak (%)	*Coulerpa Taxifolia*	*Colerpa microphysa*	*Colerpa racemose*	*Coulerpa Lentifera*	*Codium* sp.
Saturated Fatty Acid (SFA)					
1) Caprylic Acid (C8:0)	0.013±0.000	n.d	0.012±0.000	n.d	n.d
2) Capric Acid (C10:0)	0.011±0.000	n.d	0.013±0.000	0.004±0.002	n.d
3) Lauric Acid (C12:0)	0.028±0.000	0.017±0.000	0.121±0.003	0.020±0.014	0.037±0.001
4) Undecanoic Acod (C11:0)	n.d	n.d	n.d	0.033±0.000	n.d
5) Myristic Acid (C14:0)	0.186±0.001	0.083±0.000	0.139±0.003	0.108±0.055	0.054±0.001
6) Pentadecanoic Acid (C15:0)	n.d	n.d	n.d	0.013±0.004	n.d
7) Palmitic Acid (C16:0)	1.026±0.008	0.673±0.005	0.821±0.024	1.084±0.504	0.452±0.000
8) Stearic Acid (C18:0)	0.061±0.001	0.035±0.000	0.058±0.001	0.070±0.027	0.037±0.001
9) Behenic Acid (C22:0)	0.011±0.000	n.d	n.d	n.d	0.010±0.000
10) Lignoceric Acid (C24:0)	0.077±0.000	0.066±0.002	0.059±0.002	0.047±0.028	0.020±0.000
Total SFA	1.414±0.010	0.873±0.007	1.222±0.033	1.369±0.607	0.609±0.003
Monosaturated Fatty Acid (MUFA)					
1) Myristoleci Acid (C14:1)	n.d	n.d	n.d	0.011±0.004	n.d
2) Palmitoleic Acid (C16:1)	0.066±0.001	0.044±0.00	0.042±0.001	0.036±0.007	0.013±0.000
3) Heptadekenoic Acid (C17:1)	n.d	n.d	n.d	0.016±0.010	0.050±0.000
4) Oleic Acid (C18:1n9c)	0.094±0.001	0.107±0.003	0.069±0.002	0.113±0.035	0.209±0.003
Total MUFA	0.160±0.002	0.151±0.003	0.111±0.003	0.177±0.056	0.272±0.003
Polyunsaturated Fatty Acid (PUFA)					
1) Linoleic Acid (C18:2n6)	0.158±0.001	0.107±0.002	0.084±0.002	0.054±0.017	0.101±0.001
2) Linolenic Acid (C18:3n3)	0.156±0.001	0.053±0.000	0.105±0.002	0.159±0.019	0.050±0.001
3) Linolenat Acid (C18:3n6)	0.010±0.000	0.120±0.002	0.110±0.002	0.070±0.022	0.008±0.000
4) Eikosatrienoat Acid (C20:3n6)	0.010±0.000	n.d	n.d	n.d	n.d
5) Arakidonat Acid (C20:4n6)	0.016±0.000	0.014±0.000	0.033±0.006	0.016±0.006	0.023±0.001
6) Eikosapentaenoat Acid/EPA (C20:5n3)	0.033±0.001	n.d	0.019±0.004	n.d	0.010±0.000
7) Dokosaheksaenoat/DHA (C22:6n3)	n.d	n.d	n.d	n.d	0.011±0.000
Total PUFA	0.383±0.003	0.294±0.004	0.350±0.016	0.300±0.064	0.203±0.003
Total Fatty Acid					

n.d: not detected; SFA: Saturated Fatty Acids; MUFA: Monounsaturated Fatty Acids; PUFA: Polyunsaturated Fatty Acids; TFA: Total Fatty Acids.

DISCUSSION

The quality of protein in a material is determined by its amino acid composition. High-quality protein is defined as a protein that includes all essential amino acids. Amino acids are categorized into essential and non-essential types. Essential amino acids are those that the human body cannot synthesize and must be obtained through dietary sources. Non-essential amino acids are those that the human body can synthesize **(Nuryanto *et al.*, 2023)**. Amino acids serve as the fundamental building blocks of proteins, establishing a close relationship between the two. The highest total essential, non-essential, and overall amino acids were found in *C. taxifolia* seaweed and the lowest in *C. lentillifera*. This is in line with the research of **Jumsurizal *et al*. (2021)**, which reported that the protein content of *C. taxifolia* from Natuna Regency waters, Kepulauan Riau, was 11.02% higher than *C. racemosa* seaweed at 10.41%. **Ilhamdy *et al*. (2020)** reported that the protein content of green seaweed from the Natuna and Tanjungpinang waters for the *Codium* sp. species was 6.84%, while *C. microphysa* exhibited a protein content of 8.97%. **Windarto *et al*. (2021)** also reported that the protein content of *C. racemosa* from Jepara waters was 7.20%. The protein content of *C. lentillifera* from Kei Maluku waters is 5.63% **(Tapotubun, 2018)**, while that from cultivation in Karawang waters, West Java, is 7.11% **(Iskandar *et al*., 2024)**.

Seaweed exhibits a higher protein content than terrestrial plants. Variations in protein and amino acid levels can result from species differences and factors such as the harvesting season, body size, environmental temperature, maturity stage, and nutrient availability **(Sudhakar *et al*., 2009; Nurjanah *et al*., 2024)**. The highest protein content in seaweed is observed during winter, while the lowest levels occur in summer. Seasonal variations in protein levels may result from changes in environmental factors, such as light intensity and nitrogen storage **(Handayani, 2021)**. *U. lactuca*, a green seaweed from Cibuaya Beach, exhibits a protein content of 14% when collected during the rainy season **(Nurjanah *et al*., 2024)**. In contrast, *U. lactuca* from Sekotong waters in West Nusa Tenggara, collected in summer, shows a protein content of 7.17% **(Nufus *et al*., 2017)**. Nutrients present in water can enhance amino acid content, particularly nitrogen and phosphorus **(Iskandar *et al*., 2024)**. Amino acid synthesis in seaweed cells begins with the reduction of nitrate to nitrite in the cytosol, which is then reduced to ammonium for amino acid synthesis. Phosphorus can stimulate the synthesis of amino acids alanine and glycine **(Xu *et al*., 2020)**.

In the species *C. taxifolia*, *C. microphysa*, *C. racemosa*, and *Codium* sp., eight types of essential amino acids were identified, whereas *C. lentillifera* exhibited seven types due to the absence of histidine in the analysis. Seven non-essential amino acids were identified in all species. The highest amino acid in the five seaweed species from the study was glutamic acid. The study's results indicated the glutamic acid amino acid content as follows: *C. taxifolia* (1.199%), *C. microphysa* (0.731%), *C. racemosa* (1.002%), *C. lentillifera* (0.406%), and *Codium* sp. (0.610%). **Lalitha and Dhandapani**

(2018) identified several species of green seaweed, including *C. racemosa*, *Ulva lactuca*, *Ulva reticulata*, *Codium tomentosum*, and *C. sertularioides*, from the coastal region of Mandapam, Tamil Nadu, India. These species were found to contain nine essential amino acids (arginine, histidine, isoleucine, leucine, lysine, phenylalanine, threonine, valine, and methionine) and seven non-essential amino acids (aspartic acid, alanine, glutamic acid, glycine, proline, serine, and tyrosine). Amino acids present in both free and bound forms. The findings indicated that glutamic acid was the predominant amino acid across all species examined. The glutamic acid content is as follows: *C. racemosa* (14.3%), *U. lactuca* (11.8%), *U. reticulate* (13.1%), *Codium tomentosum* (13.8%), and *C. sertularioides* (16.3%). **Iskandar *et al*. (2024)** reported that the predominant amino acid in *C. lentillifera* from a cultivation center in the waters of Karawang, West Java, was glutamic acid, present at 0.840%. **Meiyasa *et al*. (2024)** reported that glutamic acid was the most abundant amino acid in the green seaweed *U. reticulata* from the waters of Moudolung, East Sumba, with a concentration of 0.3369%. Glutamic acid represents the most prevalent amino acid across all species. The concentration of methionine was observed to be low across all species of green seaweed examined from brackish waters in the Mekong Delta, Vietnam **(Anh, 2020)**. Previous research indicates that seaweed is typically abundant in glycine and alanine, while it contains low levels of histidine **(Nunes *et al*., 2017)**.

Amino acids contribute to the flavor profile of seaweed and its derivative products. Amino acids influence sweet, sour, bitter, and umami flavors based on the specific type and concentration of the amino acid **(Kawai *et al*., 2012)**. The sweet taste can originate from the amino acids serine, glycine, alanine, and proline. The bitter taste is associated with the amino acids arginine, histidine, isoleucine, methionine, tyrosine, and phenylalanine. The umami flavor is derived from aspartic and glutamic acids **(Jönsson *et al*., 2023)**. The main amino acids in seaweed protein are aspartic and glutamic acids, which contribute to the umami flavor **(Imchen, 2021)**. Seaweed is characterized by high levels of aspartic and glutamic acids, contributing to its distinctive flavor and aroma **(Nunes *et al*., 2017)**. Amino acids play significant physiological roles, such as regulating food intake, influencing gene expression, facilitating protein phosphorylation, and enabling intercellular communication **(Wu, 2013)**. Amino acids serve distinct physiological roles that contribute to the management of certain diseases. Supplementation with methionine has shown effectiveness in patients with multiple sclerosis **(Singhal *et al*., 2018)**. Arginine therapy may provide neuroprotective effects following brain ischemic injury **(Chen *et al*., 2020)**. Histidine has been found to enhance insulin sensitivity and reduce hyperinsulinemia, while glycine supplementation can aid in mitigating liver and lung injury **(Lee & Kim, 2019)**.

Fatty acids are the primary constituents of fat structure, contributing to numerous biological and metabolic functions. High-quality fat maintains a balance among saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), and polyunsaturated fatty acids

(PUFA). It contains the optimal proportion of omega-3 and omega-6, which are beneficial for human health **(Khotimchenko, 2023)**. The highest total SFA, MUFA, and PUFA were found in *C. taxifolia* seaweed. This finding is consistent with the research by **Jumsurizal *et al*. (2021)**, which indicated that the total fat content of *C. taxifolia* from Natuna waters is 1.92%, surpassing that of *C. racemosa* at 10.41%. **Ilhamdy *et al*. (2020)** also reported that the total fat content of green seaweed from Natuna and Tanjungpinang waters for the *Codium* sp. species was 1.09%, and that of *C. microphysa* was 8.97%. Research conducted by **Iskandar *et al*. (2024)** also reported that wild *C. lentillifera* yields were 0.99%, slightly different from cultivated yields of 1.105%.

Green seaweed generates the highest types of SFA, totaling eight, with palmitic acid (C16:0) being the most prevalent. This fatty acid contributes to membrane stability and serves as an energy reserve. Then there are four types of MUFA, with oleic acid (C18: 1n9c) being the most dominant and having the potential as a source of healthy vegetable oil similar to olive oil **(Nollet & Ahamad, 2024)**. There are seven types of PUFA, with linoleic acid (C18: 2n6) and linolenic acid (C18: 3n3) as the dominant. These fatty acids are significant in regulating blood pressure and brain function and preventing degenerative diseases **(Yuan *et al*., 2023)**.

C. taxifolia exhibited increased SFA content, likely associated with an energy storage strategy to endure more fluctuating environmental conditions **(Ksenia, 2024)**. The lower MUFA content compared to SFA and PUFA suggests that green seaweeds act more as a source of essential fatty acids than a stable sole fat source. This supports the findings of **Zhang *et al*. (2023)**, who stated that green seaweeds are more beneficial as a healthy dietary supplement than as the main vegetable oil. The elevated PUFA content in *C. taxifolia* may correlate with its deeper habitat, which mitigates PUFA degradation caused by UV light **(Łuczaj *et al*., 2023)**. Variations in fatty acid composition across species indicate metabolic adaptations to their respective environments **(Khotimchenko, 2023)**. The composition of fatty acids in seaweeds is significantly affected by environmental factors, including temperature, salinity, and nutrient availability **(Jaworowska & Murtaza, 2023)**.

CONCLUSION

Green seaweeds sourced from the waters of the Kepulauan Riau exhibits the highest concentrations of amino acids, particularly glutamic acid, as well as SFA and PUFA. Green seaweed presents significant potential for application in the functional food industry.

REFERENCES

Abd Halim, N. A.; Yusoff, F. M.; Mat Jais, A. M. and Ariff, A. B. (2019). Fatty acid composition and potential health benefits of Caulerpa lentillifera. International Journal of Allied Health Sciences., 3(2): 369.

Ahn, N.T.N. (2020). Nutritional Values of Green Seaweed Cladophoraceae Inbrackish Water Bodies in The Mekong delta, Vietnam. International Journal of Fisheries and Aquatic Studies., 8(1): 282-286.

Bingrui, L.; Kenneth, T. K.; Stefanie, W.; Anna K. J. and Staerk. (2023). Edible seaweed as future functional food: Identification of α-glucosidase inhibitors by combined use of high-resolution α-glucosidase inhibition profiling and HPLC–HRMS–SPE–NMR. Food Chemistry, 204: 16-22.

Chen, S.F.; Pan, M.X.; Tang, J.C.; Cheng, J.; Zhao, D.; Zhang, Y.; Liao, H.B.; Liu, R.; Zhuang, Y.; Zhang, Z.F.; Chen, J.; Lei, R.X.; Li, S.F.; Li, H.T.; Wang, Z.F. and Wan, Q. (2020). Arginine is Neuroprotective Through Suppressing HIF-1/LDHA-mediated Inflammatory Response After Cerebral Ischemia/Reperfusion Injury. *Molecular Brain*, 13:63: 1-13.

Chia, J. S, (2021). Fatty acid composition of green seaweed Caulerpa lentillifera and its potential as functional food. Journal of Marine Sciences, 29(4), 301-312.

Handayani, T. (2021). Macroalgae Diversity in Kendari Bay and Surrounding Waters, Southeast Sulawesi. Oceanol Limnol Indones, 6(1): 55–69.

Ilhamdy, A.F.; Jumsurizal; Bahari, S. M.; Azwin, B. and Pratama, G. (2020). Karakteristik Rumput Laut Hijau (*Caulerpa microphysa* dan *Codium* sp.) dari Perairan Kepulauan Riau [Characteristics of Green Seaweed (*Caulerpa microphysa* and *Codium* sp.) from Kepulauan Riau Waters]. Jurnal Sumberdaya Akuatik Indopasifik, 4(1):1-8. In Indonesian Language.

Imchen, T. (2021). Nutritional Value of Seaweeds and Their Potential to Serve as Nutraceutical Supplements. Phycologia., 60(6): 534–546.

Iskandar, I.; Winarni, D. and Mustahal, R. (2023). Kandungan asam amino *Caulerpa lentillifera* hasil budidaya dalam wadah terkontrol. Jurnal Penelitian Budidaya dan Pengolahan Biota Laut., 18(2): 45-52.

Iskandar, N.A.; Santoso, J.S.; Uju, A. and Sinurat, E. (2024). Komposisi Kimia, Profil Asam Amino dan Kualitas Protein *Caulerpa lentillifera* Hasil Budidaya pada Wadah Terkontrol [Chemical Composition, Amino Acid Profile and Protein Quality of *Caulerpa lentillifera* Cultivated in Controlled Containers]. Jurnal Pascapanen dan Bioteknologi Kelautan dan Perikanan, 19(1): 37-50. In Indonesian Language.

Jaworowska, A. and Murtaza, A. (2023). Seaweed Derived Lipids Are a Potential Anti-Inflammatory Agent: A Review. International Journal of Environmental Research and Public Health, 20(730): 5.

Jönsson, M.; Merkel, A.; Fredriksson, C.; Karlsson, E. N. and Wendin, K. (2023). Nutritional, Physicochemical, and Sensory Characterization of Four Common Northern European Seaweed Species Intended for Food. Algal Research, 75: 103258.

Jumsurizal; Ilhamdy, A.F. and Astika, A. (2021). Karakteristik Kimia Rumput Laut Hijau (*Caulerpa racemosa & Caulerpa taxifolia*) dari Laut Natuna, Kepulauan Riau, Indonesia [Chemical Characteristics of Green Seaweed (*Caulerpa racemosa* and *Caulerpa taxifolia*) from Natuna Sea, Kepulauan Riau, Indonesia]. 6(1):19-24. In Indonesian Language.

Kawai, M.; Sekine-Hayakawa, Y.; Okiyama, A. and Ninomiya, Y. (2012). Gustatory Sensation of L- and D-amino Acids in Humans. Amino Acids, 43(6):2349–2358.

Khotimchenko, S. V. (2023). Environmental factors affecting the lipid composition of seaweeds. Phycological Research, 71(1), 56-74.

Ksenia, C.. (2024). Algal Adaptation to Environmental Stresses: Lipidomics Research. Int. J. Plant Biol. 2024, 15, 719–732.

Lalitha, N and Dhandapani, R. (2018). Proximate Composition and Amino Acid Profile of Five Green Algal Seaweeds from Mandapam Coastal regions, Tamil Nadu, India. The Pharma Innovation Journal, 7(10):400-403.

Lee, D.Y. and Kim, E.H. (2019) Therapeutic E ects of Amino Acids in Liver Diseases: Current Studies and Future Perspectives. Journal of Cancer Prevention, 24(2): 72–78.

Łuczaj, W., Gęgotek, A., Conde, T., Domingues, M. R., Domingues, P. and Skrzydlewska, E. (2023). Lipidomic assessment of the impact of Nannochloropsis oceanica microalga lipid extract on human skin keratinocytes exposed to chronic UVB radiation. Scientific Reports, 13(22302): 2-3.

Nollet, L. M. L. and Ahamad, J. (Eds.). (2025). Bioactive compounds of edible oils and fats: Health benefits, risks, and analysis. CRC Press.

Nufus, C.; Nurjanah, A. and Abdullah, A. (2017). Characteristics of Green Seaweeds from Seribu Islands and Sekotong West Nusa Tenggara Antioxidant. Jurnal Pengolahan Hasil Perikanan Indonesia, 20(3): 620-632.

Nunes, N.; Ferraz, S.; Valente, S.; Barreto, M.C. and Pinheiro de Carvalho, M.A.A. (2017). Biochemical Composition, Nutritional Value, and Antioxidant Properties of Seven Seaweed Species from The Madeira Archipelago. Journal of Applied Phycology, 29(5): 2427-2437.

Nurjanah; Nurilmala, M.; Alfarizi, S.; Rochima, E.; Wahyuni, D.S. and Seulalae, A.V. (2024). Characterization of seaweed healthy salt from Indonesian Ulva lactuca and Chaetomorpha sp. flour. BIO Web of Conferences 112, 09002 (2024) 6th EMBRIO International Symposium (EIS 2023).

Nuryanto; Putri, A.R.; Chasanah, E.; Sulchan, M.; Afifah, D. N.; Martosuyono, P. and Asmak, N. (2023). Profil Asam Amino Makanan Pendamping ASI (MP-ASI) Protein Hidrolisat Ikan Kuniran [Amino Acid Profile of Complementary Breast Milk Food (MP-ASI) Hydrolyzed Protein of Kuniran Fish]. Journal of Nutrition College, 12(3): 232-237. In Indonesian Language.

Philip C.C (2024). N-3 Polyunsaturated fatty acids, inflammation, and inflammatory diseases1–3. Frontiers in Nutrition, 10: 108453.

Sanjaya, Y.A; Widjanarko; Setijawati, D. and Masruri (2017). Potential Of Bioactive Antioxidant Compounds And Chemical Composition Of Fresh, Semi-Dry, And Dry Green Seaweeds Caulerpa Racemosa. Repository Universitas Bawijaya: 1-156.

Simopoulos, A. P. (2022). The importance of the omega-6/omega-3 fatty acid ratio in human health. Journal of Nutritional Biochemistry, 99: 108841.

Singhal, N.K.; Freeman, E.; Arning, E.; Wasek, B.; Clements, R.; Sheppard, C.; Blake, P.; Bottiglieri, T. and McDonough, J. (2018). Dysregulation of Methionine Metabolism in Multiple Sclerosis. Neurochemistry International, 112: 1–4.

Sudhakar, M.; Manivannan, K. and Soundrapandian, P. (2009). Nutritive Value of Hard and Soft Shell Crabs of *Portunus sanguinolentus* (Herbst). International Journal of Animal and Veterinary Advances, 1(2): 44–48.

Tapotubun, A. M. (2018). Komposisi Kimia Rumput Laut (*Caulerpa lentillifera*) dari Perairan Kei Maluku dengan Metode Pengeringan Berbeda [Chemical Composition of Seaweed (*Caulerpa lentillifera*) from Kei Maluku Waters with Different Drying Methods]. Jurnal Pengolahan Hasil Perikanan Indonesia, 21(1): 13-23.

Windarto, S.; Prastiwahyudi, A.H.; Susilowati, T.; Haditomo, A.H.C. and Harwanto, D. (2021). Effect of Different Substrates on Growth and Protein Content of Caulerpa racemosa. Journal of Hunan University., 48(7): 266-275.

Wu, G. (2013). Amino Acids: Biochemistry and Nutrition, 1st ed.CRC Press: Boca Raton, FL, USA.

Xu, N.; Xu, K.; Wang, W.; Xu, Y.; Ji, D.; Chen, C. and Xie, C. (2020). Nutrient Enrichment Improves Growth and Food Quality of Two Strains of The Economic Seaweed Pyropia haitanensis. Frontiers in Marine Science., 7:1-10.

Zhang, M., Ma, Y., Che, X., Huang, Z., Chen, P., Xia, G. and Zhao, M. (2020). Comparative analysis of nutrient composition of Caulerpa lentillifera from different regions. Journal of Ocean University of China, 19(2): 439-445.

Zhang, X.; Li, Y.; Chen, J.; Wang, L. and Zhao, H. (2023). Fatty acid composition and nutritional evaluation of Caulerpa lentillifera from different regions. Foods, 14(3): 474.