Nutritional composition and amino acid profiles of six tropical seaweeds from central Vietnam: preliminary insights into marine bioresource potential

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Abstract. This study provides a preliminary assessment of the nutritional composition and amino acid profiles of six economically important seaweed species collected from the coastal waters of Phu Yen Province, central Vietnam. Protein, lipid, ash, and amino acid compositions were determined by an accredited analytical laboratory using standardized analytical procedures. The studied species included *Chaetomorpha aerea*, *Caulerpa racemosa*, *Turbinaria ornata*, *Sargassum mcclurei*, *Gracilaria tenuistipitata*, and *Gracilaria salicornia*. Protein content varied considerably among species, ranging from 0.84% to 17.20% dry weight (DW), with *G. tenuistipitata* exhibiting the highest value. Lipid content remained below 1% in all species, whereas ash content indicated substantial mineral accumulation, particularly in brown seaweeds. Sixteen amino acids were identified, including essential amino acids such as lysine, leucine, isoleucine, and valine. Glutamic acid and aspartic acid were the dominant amino acids across all species. Principal component analysis (PCA) indicated compositional differences among species. This dataset represents one of the first baseline studies on seaweed nutritional composition from central Vietnam. The findings contribute to understanding regional marine bioresources and suggest that selected seaweed species may serve as alternative protein sources for food and aquaculture applications. This preliminary study provides indicative compositional trends rather than statistically validated differences.
Keywords: essential amino acids, functional food resources, macroalgae, principal component analysis, protein quality, proximate composition.

Introduction. Marine macroalgae have gained increasing attention as valuable marine bioresources because of their high nutritional value, diverse functional properties, and increasing relevance to sustainable food systems and marine-derived functional ingredients (Fleurence, 1999; Holdt & Kraan, 2011; Biris-Dorhoi et al., 2020; Peñalver et al., 2020; Healy et al., 2023; Matos et al., 2024). They contain proteins, essential amino acids, minerals, vitamins, dietary fiber, and bioactive compounds, making them suitable for food, aquaculture, nutraceutical, and functional ingredient applications (Burtin 2003; Leandro et al., 2020; Healy et al., 2023; Matos et al., 2024). Macroalgae have also been increasingly recognized as sustainable alternative protein resources with potential applications in future food systems (O'Brien et al., 2022; Pereira et al., 2024). Compared with terrestrial plant proteins, macroalgae may provide a more balanced amino acid composition, particularly with respect to lysine, which is often limited in cereal-based diets (Food and Agriculture Organization of the United Nations, 2013; Cherry et al., 2022).

The nutritional composition of macroalgae varies depending on species, environmental conditions, season, and geographic location (Dawczynski et al., 2007). Among nutritional components, amino acid composition is particularly important because essential amino acids are critical indicators of protein quality and nutritional value. Amino acid profiling is therefore widely used to evaluate the suitability of marine macroalgae as alternative protein resources for human food and aquaculture applications and to assess protein quality and nutritional functionality (Mišurcová et al., 2014; Machado et al., 2020; O'Brien et al., 2022).

Global production and utilization of marine macroalgae have increased considerably in recent years because of their growing importance in sustainable food systems (Food and Agriculture Organization of the United Nations, 2018). Vietnam possesses extensive coastal areas with favorable environmental conditions for macroalgal growth; however, detailed studies on the nutritional characteristics of tropical macroalgae remain limited, particularly in central coastal regions. Phu Yen coastal waters support diverse macroalgal communities with potential importance for marine resource utilization.

Multivariate statistical approaches such as principal component analysis (PCA) are useful for detecting interspecific variation and identifying compositional patterns in amino acid datasets (Peñalver et al., 2020). PCA enables visualization of biochemical relationships among species and helps identify the major variables contributing to nutritional differentiation.

Therefore, the purpose of this preliminary study was to establish baseline information on the nutritional potential of six tropical macroalgal species collected from Phu Yen coastal waters, Vietnam. Specifically, the study aimed to (i) determine their protein, lipid, and ash contents; (ii) characterize their amino acid profiles; and (iii) use PCA to explore interspecific compositional patterns relevant to their prospective use as food ingredients and aquaculture feed resources.

Material and Method

Sample collection. Macroalgal samples were collected from two coastal ecosystems in Phu Yen Province, central Vietnam, during May 2019 under low tide conditions. Sampling areas included the My Quang coastal area and O Loan Lagoon. The study focused on nutritionally important macroalgal species with relatively high local biomass availability.
Six macroalgal species were selected for biochemical characterization. Five species collected from the My Quang coastal area were *Chaetomorpha aerea*, *Caulerpa racemosa*, *Turbinaria ornata*, *Sargassum mcclurei*, and *Gracilaria salicornia*, whereas *Gracilaria tenuistipitata* was collected from O Loan Lagoon. Healthy and visually intact thalli without obvious physical deterioration or extensive epiphytic overgrowth were manually collected to obtain representative material for nutritional analyses.

Immediately after collection, samples were rinsed with ambient seawater to remove sediment and attached debris and transported to the laboratory under cooled conditions. Samples were subsequently washed thoroughly with distilled water, air-dried at room temperature, and oven-dried at 50°C to constant weight prior to biochemical analyses. Dried materials were ground into fine powder and stored in airtight containers at 4°C until proximate composition and amino acid analyses.

Proximate composition analysis. Protein, lipid, and ash contents were determined by the CASE Analytical Services and Experimentation Center (Ho Chi Minh City, Vietnam) using accredited analytical methods. Protein content was determined according to CASE.NS.0009 (Food and Agriculture Organization of the United Nations, 1986) based on total nitrogen determination and calculated using a nitrogen-to-protein conversion factor of 6.25. Lipid content was analyzed according to CASE.NS.0008 (Food and Agriculture Organization of the United Nations, 1986), and ash content was determined following TCVN 4327:2007. Results are presented as validated analytical values provided by the accredited laboratory and expressed on a dry weight (DW) basis.

Amino acid analysis. Amino acid composition was determined by the CASE Analytical Services and Experimentation Center according to TCVN 8764:2012 (ISO 13903:2005). Amino acid concentrations were quantified and expressed as g 100 g^{-1} DW. Results are reported as validated analytical values provided by the accredited laboratory. Amino acids that are susceptible to degradation during acid hydrolysis may be underestimated under the analytical conditions employed.

***Data* analysis**. This study was designed as a preliminary assessment to provide baseline compositional information on selected tropical macroalgae. Descriptive statistical analysis was performed, and PCA was applied as an exploratory tool to visualize compositional variation among species. PCA was conducted using XLSTAT 2023 software (Addinsoft, France). Results are presented as validated analytical values provided by the accredited laboratory and expressed on a DW basis. Because pooled samples and validated laboratory analytical values were used, inferential statistical analyses were not performed, and the findings should therefore be interpreted as indicative compositional trends rather than statistically validated differences.

Results

Proximate composition (protein, lipid, and ash). The proximate composition (lipid, protein, and ash contents) of the six studied seaweed species is presented in Table 1.

Table 1

Proximate composition (lipid, protein, and ash) of six seaweed species collected from Phu Yen coastal waters (DW basis).

Species	*Lipid (%)*	*Protein (%)*	*Ash (%)*
Chaetomorpha aerea	0.24	0.84	3.22
Caulerpa racemosa	0.18	2.50	4.10
Turbinaria ornata	0.67	4.23	16.70
Sargassum mcclurei	0.10	6.80	33.20
Gracilaria tenuistipitata	0.10	17.20	17.40
Gracilaria salicornia	0.14	1.07	4.00

Note: Values are expressed on a dry weight (DW) basis.

Protein content varied considerably among species, ranging from 0.84% to 17.20% DW. The highest protein content was observed in *G. tenuistipitata* (17.20%), followed by *S. mcclurei* (6.80%) and *T. ornata* (4.23%). In contrast, lower protein contents were recorded in *C. racemosa* (2.50%), *G. salicornia* (1.07%), and *C. aerea* (0.84%).

Lipid content remained low across all studied species, ranging from 0.10% to 0.67%, which is consistent with previous reports on marine macroalgae (Fleurence 1999; Matanjun et al., 2009). The highest lipid content was detected in *T. ornata* (0.67%), whereas the lowest value was observed in *G. tenuistipitata* (0.10%).

Ash content varied markedly among species, ranging from 3.22 to 33.20%. The highest ash content was recorded in *S. mcclurei* (33.20%), while *C. aerea* exhibited the lowest value (3.22%). Overall, red and brown macroalgae tended to exhibit relatively higher protein and mineral contents than green macroalgae; however, these observations should be interpreted as descriptive compositional trends because inferential statistical analyses were not performed in the present preliminary study.

Amino acid composition. The amino acid composition of the studied seaweed species is presented in Table 2. Amino acid concentrations were expressed as g 100 g^{-1} DW rather than as a percentage of total protein.

All six species contained a total of 16 amino acids, including essential amino acids such as lysine, leucine, isoleucine, valine, methionine, phenylalanine, threonine, and histidine. The presence of these essential amino acids indicates the potential nutritional value of the studied macroalgae as alternative protein resources for food and aquaculture applications.

Among the detected amino acids, glutamic acid and aspartic acid were the dominant components across all species. Glutamic acid concentrations ranged from 0.38 to 1.35 g 100 g^{-1} DW, whereas aspartic acid varied from 0.35 to 1.17 g 100 g^{-1} DW. Relatively high arginine concentrations were also observed, particularly in G. tenuistipitata (1.23 g 100 g^{-1} DW).

Notably, *G. tenuistipitata* exhibited the highest overall amino acid concentrations among the studied species, especially for glutamic acid and aspartic acid. In contrast, *C.*

aerea and *C. racemosa* generally showed comparatively lower amino acid concentrations. The predominance of glutamic acid and aspartic acid is consistent with previous reports on marine macroalgae and may contribute to the characteristic umami-related properties associated with edible seaweeds (Fleurence 1999; Mišurcová et al., 2014).

Table 2

Amino acid composition of six seaweed species collected from Phu Yen coastal waters

Amino acid (g 100 g^{-1} DW)	*Chaetomorpha aerea*	*Caulerpa racemosa*	*Turbinaria ornata*	*Sargassum mcclurei*	*Gracilaria tenuistipitata*	*Gracilaria salicornia*
Alanine	0.35	0.35	0.23	0.40	0.86	0.48
Arginine	0.13	0.15	0.10	0.20	1.23	0.31
Aspartic acid	0.51	0.46	0.35	0.56	1.17	0.68
Glutamic acid	0.69	0.57	0.38	1.13	1.35	0.73
Glycine	0.30	0.29	0.16	0.33	0.71	0.41
Histidine	0.06	0.04	0.04	0.08	0.18	0.04
Isoleucine	0.19	0.22	0.11	0.23	0.57	0.33
Leucine	0.34	0.35	0.17	0.38	0.76	0.47
Lysine	0.29	0.15	0.13	0.27	0.70	0.31
Methionine	0.09	0.07	0.06	0.08	0.08	0.05
Phenylalanine	0.33	0.32	0.20	0.32	0.62	0.44
Proline	0.16	0.14	0.06	0.13	0.56	0.26
Serine	0.23	0.25	0.11	0.23	0.58	0.35
Threonine	0.24	0.25	0.11	0.25	0.55	0.32
Tyrosine	0.22	0.24	0.17	0.21	0.27	0.20
Valine	0.30	0.31	0.17	0.31	0.68	0.42

Note: DW = dry weight.

The relative distribution of glutamic acid, aspartic acid, and arginine among species is illustrated in Figure 1, highlighting the comparatively higher concentrations observed in *G. tenuistipitata* and *S. mcclurei*. Because the present study was designed as a preliminary compositional assessment, EAA/NEAA ratios were not calculated and should be addressed in future studies with expanded datasets.

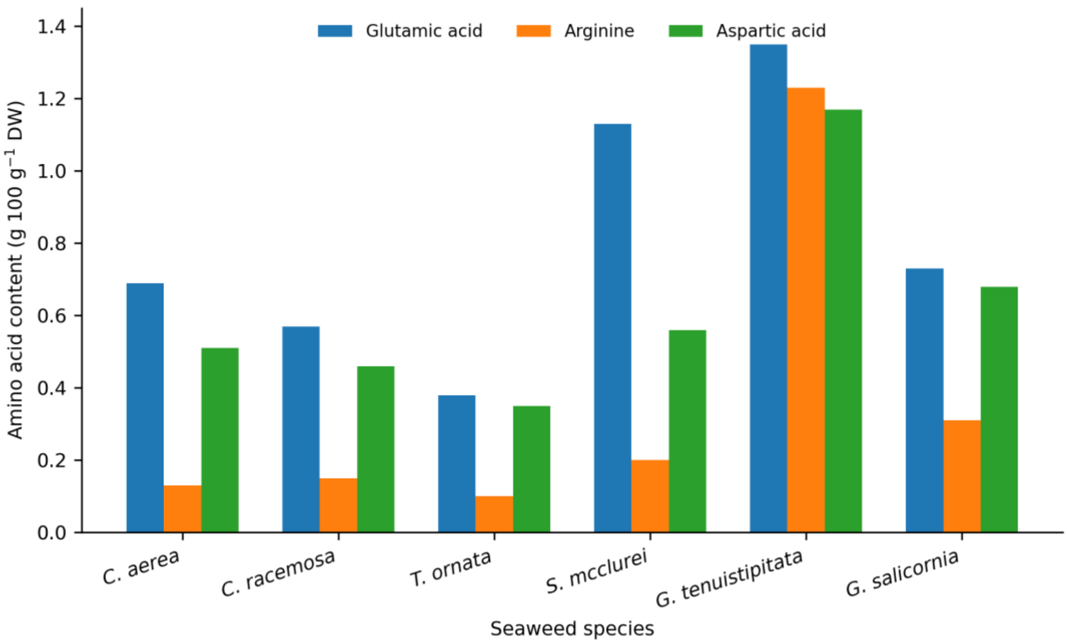

Figure 1. Contents of glutamic acid, arginine, and aspartic acid in six seaweed species collected from Phu Yen coastal waters.

Principal component analysis (PCA). PCA was performed using normalized amino acid concentrations expressed as g 100 g^{-1} DW to evaluate compositional variation among the studied seaweed species. The PCA results are presented in Figure 2.

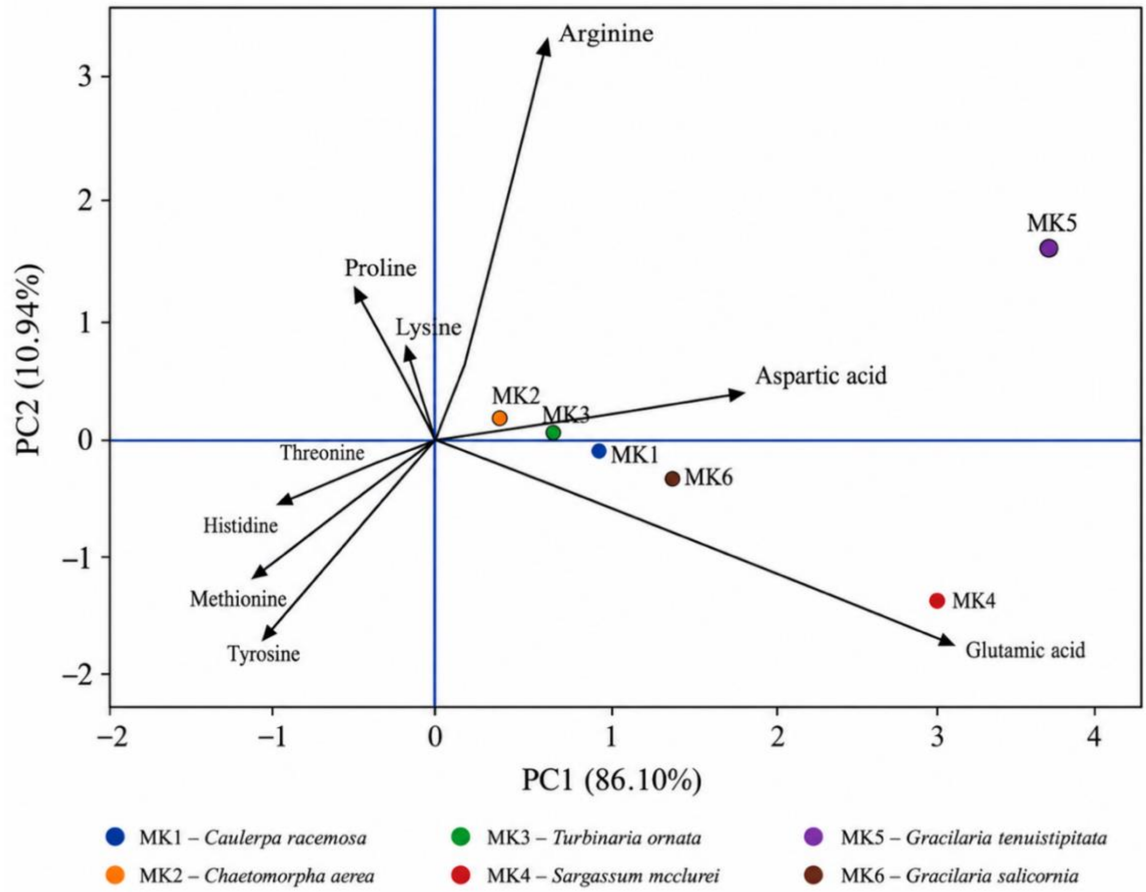

Figure 2. Principal component analysis of amino acid composition in six seaweed species from Phu Yen coastal waters.

The first two principal components (PC1 and PC2) explained 97.03% of the total variance, with PC1 accounting for 86.10% and PC2 accounting for 10.94%. This high cumulative variance indicates that the PCA effectively summarized the variability in amino acid composition among species.

The PCA plot revealed clear separation among species, reflecting differences in biochemical composition. *G. tenuistipitata* (MK5) was distinctly separated along the positive axis of PC1, indicating comparatively higher amino acid concentrations. *S. mcclurei* (MK4) also occupied a distinct position, suggesting a differentiated amino acid profile.

The distribution of amino acid variables indicated that glutamic acid, aspartic acid, and arginine contributed strongly to the positive side of PC1, whereas methionine, tyrosine, and histidine were associated with the negative side of PC2. Arginine also showed a relatively strong contribution along PC2, indicating its role in differentiating species.

Overall, the PCA results support the variation observed in amino acid composition among the studied macroalgae and provide an integrated view of biochemical differences among species. Because the present study represents a preliminary compositional assessment, the PCA results should be interpreted as exploratory patterns rather than statistically validated clustering.

Discussion. The present study provides baseline information on the nutritional composition and amino acid characteristics of selected tropical macroalgae collected from Phu Yen coastal waters, central Vietnam. Considerable variation in protein, lipid, ash, and amino acid contents was observed among species, which is consistent with previous studies reporting that macroalgal composition is influenced by species-specific biochemical characteristics and environmental conditions (Fleurence 1999; Dawczynski et al., 2007).

Among the studied species, *G. tenuistipitata* exhibited the highest protein content and relatively high concentrations of glutamic acid, aspartic acid, and arginine. These characteristics suggest its potential suitability as an alternative marine-derived protein source for food and aquaculture applications. The relatively high protein content observed in some investigated species further highlights their nutritional importance and potential value for food development. These findings are consistent with recent studies emphasizing seaweeds as promising functional food ingredients, sustainable alternative protein resources, and marine-derived nutraceutical ingredients for future food systems (Peñalver et al., 2020; Choudhary et al., 2021; O'Brien et al., 2022; Matos et al., 2024; Pereira et al., 2024).

Similarly, *S. mcclurei* showed high ash content, indicating a strong capacity for mineral accumulation, which is commonly reported in brown macroalgae (Rupérez 2002; Kumar et al., 2011; Circuncisão et al., 2018). Such mineral-rich macroalgae may have potential applications as functional food ingredients or feed supplements and may contribute to the development of marine-derived bioactive products and nutraceutical formulations (Healy et al., 2023; Matos et al., 2024).

The predominance of glutamic acid and aspartic acid observed across species is consistent with previous reports on edible macroalgae (Mišurcová et al., 2014; Machado et al., 2020). These amino acids are associated with protein quality and may contribute to characteristic sensory properties of edible seaweeds.

The presence of essential amino acids such as lysine, leucine, isoleucine, valine, methionine, and phenylalanine further supports the nutritional potential of the studied macroalgae as complementary protein resources for human nutrition and aquaculture feed development. The increasing interest in seaweed-derived proteins and sustainable marine food resources further highlights the importance of nutritional characterization studies for supporting future food innovation and aquaculture development (O'Brien et al., 2022; Pereira et al., 2024).

The PCA results demonstrated compositional variation among species and revealed distinct biochemical patterns within different macroalgal groups. In particular, the separation of *G. tenuistipitata* and *S. mcclurei* suggests differences in amino acid composition that may be associated with metabolic characteristics and ecological adaptation. As an exploratory multivariate tool, PCA was useful for visualizing biochemical relationships among species and identifying the major amino acids contributing to interspecific variation.

Despite these promising findings, the present study has several limitations. Sampling was conducted during a single season and within a limited coastal area, and pooled samples were used for compositional assessment. Biological replication was not available because the study was designed as a preliminary baseline investigation using accredited laboratory analytical values. Consequently, inferential statistical analyses were not performed. Therefore, the findings should be interpreted as indicative compositional trends rather than statistically validated differences among species.

Future studies should include multi-seasonal sampling, expanded geographic coverage, and increased biological replication to better evaluate temporal and environmental influences on macroalgal nutritional composition. Additional investigations on maturity stage, environmental conditions, and bioactive compounds would further improve understanding of the nutritional and functional potential of tropical marine macroalgae.

The present dataset should be considered a baseline compositional resource intended to support future studies involving expanded sampling, seasonal variability assessment, and replicated experimental designs.

Conclusions. This study provides preliminary baseline information on the nutritional composition and amino acid profiles of selected tropical macroalgae collected from Phu Yen coastal waters, central Vietnam. Considerable compositional variation was observed among species, with *G. tenuistipitata* exhibiting the highest protein and amino acid contents among the studied macroalgae.

The predominance of essential amino acids, together with the elevated glutamic acid and aspartic acid concentrations observed in several species, highlights their potential nutritional and functional value. In particular, *G. tenuistipitata* and *S. mcclurei* may warrant further investigation for potential applications as functional food ingredients and aquaculture feed resources.

Although the present study represents a preliminary compositional assessment, the findings contribute valuable baseline information for future research on tropical marine bioresources in central Vietnam. Further studies involving seasonal variation, expanded sampling, and detailed nutritional evaluation are recommended to better characterize the functional potential of these macroalgae.

Acknowledgements. The author gratefully acknowledges the support received during the implementation of this study.

Authors Contributions. NTTH solely conceived and designed the study, conducted field sampling and laboratory experiments, analyzed and interpreted the data, prepared the figures and tables, and wrote, reviewed, and revised the manuscript.

Conflict of Interest. The authors declare that there is no conflict of interest.

Data Availability. The datasets supporting the findings of this study are available from the corresponding author upon reasonable request.

Funding. This research received no external funding.

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Received: 06 April 2026. Accepted: 28 May 2026. Published online: 29 August 2026.
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How to cite this article:
Hang, N. T. T. (2026). Nutritional composition and amino acid profiles of six tropical seaweeds from central Vietnam: preliminary insights into marine bioresource potential. *AACL Bioflux*, *19*(4), 1985-1992.