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The Comparison of Phytochemical Composition, Total Polysaccharides, and Highest Nutrient Content in Seaweed (*Ulva lactuca*) from Two Different Locations

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Abstract

Ulva lactuca is a source of structurally diverse and highly valuable bioactive compounds. Its chemical composition includes carbohydrates (up to 60%), proteins (10-47 %), lipids (1-3 %), and bioactive compounds such as polyphenols, which exhibit antibacterial, antiviral, antioxidant, and immunomodulatory properties. Ulvan, a heteropolysaccharide present in its cell walls, is known for its antiviral, antioxidant, and antimicrobial properties. This study aims to identify the potential of *U. lactuca* as a source of nutrition and health benefits. The research is descriptive-exploratory, aiming to analyze the phytochemical composition and total polysaccharides in *U. lactuca* from Ujung Genteng Beach, Sukabumi, West Java, and Lombok Beach, West Nusa Tenggara. The results indicate that the highest flavonoid content was found in the *U. lactuca* extract from Sukabumi, measuring 3.95 mg/L, compared to 3.686 mg/L in *U. lactuca* from Lombok. The alkaloid content in *U. lactuca* from Lombok was 26.53 mg/L, while in *U. lactuca* from Sukabumi, it was 24.78 mg/L. The highest tannin content was found in *U. lactuca* from Lombok at 9.87 mg/L, compared to 3.53 mg/L from Sukabumi. The polysaccharide content in *U. lactuca* from Sukabumi was 50.83 mg/L, whereas it was 38.165 mg/L in *Ulva* lactuca from Lombok. Proximate analysis showed that *U. lactuca* from Lombok had a higher protein content (20.44%) compared to that from Sukabumi (15.47%).

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INTRODUCTION

Ulva lactuca is a multicellular alga classified under Chlorophyta, known to contain immunologically active substances due to its cells being rich in chlorophyll (Dewi, 2018). This macroalga is considered a renewable polymer because of the unique properties of its cell wall, which contains sulfated polysaccharides (Yunita *et al.,* 2018), such as carrageenan (found in red algae), Ivan (in green algae), and fucoidan (in brown algae) (Windyaswari *et al.,* 2019). *U. lactuca* serves as a valuable source of structurally diverse bioactive compounds (Lomartire and Gonçalves, 2022). These compounds exhibit significant immunostimulatory and antimicrobial effects, making them beneficial for applications in the healthcare sector (Yunita *et al.,* 2018).

The composition of *U. lactuca* includes various bioactive substances such as proteins, lipids, and polyphenols, which exhibit antibacterial, antiviral, and antimicrobial properties (da Costa *et al.*, 2018). The bioactive compounds present in *U. lactuca,* including phlorotannins and flavonoids, play a crucial role in protecting against ultraviolet (UV) radiation and serve as natural antioxidants (Prasiddha *et al.,* 2016). The flavonoid content in *U. lactuca,* which functions as a UV-protective agent, can vary depending on its growing environment (da Costa *et al.*, 2018). *U. lactuca* is also a rich source of functional metabolites, including polysaccharides, proteins, peptides, lipids, amino acids, polyphenols, vitamins, and minerals (Putra *et al.,* 2024). Polysaccharide compounds that have been identified for their antiviral, antioxidant, antimicrobial, and immunomodulatory properties include uranonate, fucoidan, ulvan, alginate, uranylate, agarose, and carrageenan (Yu-Qing *et al.,* 2016). Additionally, *U. lactuca* contains both water-soluble and insoluble cellulose (38–52%), which aligns with its polysaccharide structure, where ulvan is the primary component (Dominguez and Loret, 2019). Ulvan, a heteropolysaccharide found in the cell walls of *U. lactuca,* plays a vital role in immune system regulation (Ramadhan *et al.,* 2022). It constitutes up to 30% of the dry weight of *U. lactuca* and primarily consists of sulfonic acid, L-rhamnose sulfate, xylose, and glucose (Violle *et al.,* 2018).

Table 1. Nutritional Content of 100 gram *Ulva lactuca.*

No	Nutritional Content	Total
1	Water (%)	16,9
2	Ash (%)	11,2
3	Protein (%)	13,6
4	Fat (%)	0,19
5	Carbohidrate (%)	58,1
6	Fiber (%)	28,4
7	Vitamin A (IU/100 g)	< 0,5
8	Vitamin B1 (mg/kg)	4,87
9	Vitamin B2 (mg/kg)	0,86
10	Sodium (mg/100 g)	364
11	Calcium (mg/100 g)	1828
12	Iron (mg/100 g)	14
13	Potassium (mg/100 g)	467

Source: Xiao-Ling *et al.* (2003).

Several studies have analyzed the composition of *Ulva lactuca*. Kidgell *et al.* (2019) reported that ulvan extracted from *U. lactuca* contains 12.80–23% sulfate, 12.73–45% rhamnose, 2–12% xylose, and 6.5–25.96% uronic acid. Arbi *et al.* (2016) found that the bioactive compounds in *U. lactuca* extract include 4.59% phenols and 0.59%

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flavonoids. Phytochemical testing of *U. lactuca* ethanol extract (70%) conducted by Rompas and Gasah (2022) revealed the presence of alkaloids, saponins, flavonoids, triterpenoids, and steroids. Additionally, Ibrahim *et al.* (2022) reported that the polysaccharide content obtained from *U. lactuca* was approximately 36.50 g/100 g, with a high sulfate content of 19.72%. Their findings also identified various monosaccharides, including fucopyranose (22.09%), L-rhamnose (18.17%), L-fucose (17.46%), rhamnopyranose (14.29%), mannopyranose (8.59%), α-D-galactopyranose (7.64%), galactopyranose (6.14%), and β-arabinopyranose (5.62%). Furthermore, da Costa *et al.* (2018) reported the proximate composition of *U. lactuca*, which consists of 62.93% carbohydrates, 5.17% lipids, 17.43% proteins, 2.94% ash, and 11.53% moisture. Xiao-Ling et *al.* (2003) reported that *U. lactuca* has a fairly high nutritional content in terms of nutritional value in 100 grams (Table 1).

The studies above suggest that *U. lactuca* contains high levels of bioactive compounds and polysaccharides, making it a potential supplement for fish health. The chemical composition of *U. lactuca* is highly diverse and influenced by several factors, including seasonal variations, species type, harvesting age (Pereira and Valado, 2023), geographical location, and surrounding environmental conditions (Santi *et al.,* 2012). This study aims to analyze the phytochemical composition, total polysaccharide content, and nutritional profile of *U. lactuca* collected from two different locations: Ujung Genteng Beach, Sukabumi, West Java, and Batu Layar Beach, Lombok, West Nusa Tenggara. In Sukabumi, where the waters are cooler with strong currents and high rainfall, *U. lactuca* may exhibit higher flavonoid levels as a response to the more challenging environmental conditions. Meanwhile, in Lombok, where the waters are warmer, calmer, and exposed to more intense sunlight, *U. lactuca* is also likely to produce high flavonoid content as protection against stronger UV radiation. The most prominent compounds found in *U. lactuca* collected from Ujung Genteng Beach, Sukabumi, West Java, are carbohydrates, consisting of ulvan (36–40%), cellulose (10%), and hemicellulose (12%) (Kidgell *et al.,* 2019). Antioxidant activity of *U. lactuca* from Batu Layar Beach, Lombok, West Nusa Tenggara, was reported at 534.76 ± 14 µg/mL, with a Total Phenolic Content (TPC) of 5.13 ± 0.8 mg mL^{-1} and 25.315 ± 2.6 mg RE g^{-1} (Prasedya *et al.,* 2019). Overall, according to Agati *et al.* (2012), adaptation to different environmental conditions in Sukabumi and Lombok influences flavonoid production in *U. lactuca*, with potentially higher concentrations serving as a protective mechanism.

METHODOLOGY

Ethical Approval

This research did not involve the use of animal subjects or human participants directly. Therefore, the submission of ethical clearance from an ethics committee does not apply to this study. This research upholds the principles of academic honesty and responsible research practices.

Place and Time

Samples were collected from two locations: Ujung Genteng Beach, Sukabumi, West Java, and Batu Layar Beach, Lombok, West Nusa Tenggara (Figure 1). The samples were obtained from the Jepara Brackish Water Fishery Center, where collection was carried out at two research sites designated for the research. The environmental conditions at the surface of Ujung Genteng Beach during sampling were: temperature 26°C, salinity 30 ppt, and pH 7.1. At Batu Layar Beach, the surface conditions were: temperature 28°C, salinity 35 ppt, and pH 7.5.

This research was conducted at the Laboratory of Fish Diseases and Health, Aquaculture Department, Universitas Brawijaya; the Laboratory of Fisheries Product Safety, Fisheries Product Technology Department, Universitas Brawijaya; the Laboratory of Food Quality and Safety Testing, Faculty of Agricultural

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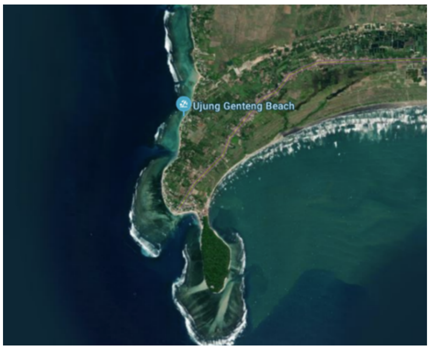
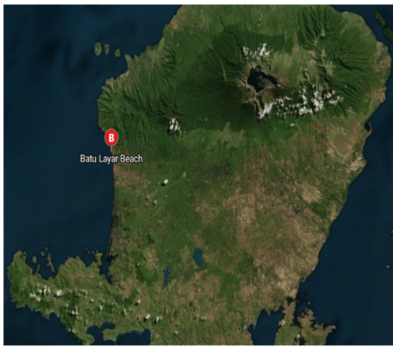
Technology, Universitas Brawijaya; and the Integrated Laboratory, Faculty of Agricultural Technology, Universitas Brawijaya.

Research Materials

The test fish used in this study were African catfish juveniles with a length between 7-8 cm, with an average weight of 2.7 ± 0.2 g. Selection is carried out by paying attention to uniformity in size, completeness of organs, and health of the fish. Fish were obtained from a CPIB-certified catfish hatchery (UPR. Raja Lele Situbondo, No. 1699.2905.A1.B0-Form CPIB19). The fish pond used in this study was a catfish rearing pond, a tarpaulin pond with a diameter of 3 m and a height of 1 m. Salt was used as a sterilization material. The feed used is commercial feed that has a protein content of 30-32%.



Ujung Genteng Beach, Sukabumi



Batu Layar Beach, Lombok

Figure 1. Two-Location Sampling Sites.

Work Procedure

Preparation of *Ulva latuca* Extract

The extraction process of *U. lactuca*, as described by Gazali *et al.* (2024) begins with weighing 10 grams of *U. lactuca* powder, which is then mixed with 200 mL of 70% ethanol. The maceration process is carried out for 18 hours, with the mixture being shaken every 6 hours. After maceration, the *U. lactuca* solution is heated using a water bath and subsequently filtered using filter paper. The obtained *U. lactuca* extract is then dried until a concentrated, dry extract is formed.

Determination of Flavonoid Compounds

The determination of flavonoid compounds begins with weighing 25 mg of extract and dissolving it in 10 mL of ethanol to obtain a concentration of 2500 ppm. From this solution, 1 mL is taken and mixed with 3 mL of methanol, 0.2 mL of 10% $AlCl_3$, 0.2 mL of 1 M potassium acetate, and distilled water until the total volume reaches 10 mL. The sample is then incubated at room temperature for 30 minutes. Absorbance is measured using a UV-Vis spectrophotometer at a wavelength of 431 nm. Each sample is analyzed in triplicate to obtain the average absorbance value.

Determination of Alkaloid Compounds

The determination of alkaloid compounds, as described by Karim *et al.* (2023), begins by dissolving 0.1 grams of extract in 10 mL of ethanol and shaking until homogeneous to obtain a concentration of 10,000 ppm. From this solution, 1 mL is taken and mixed with 10 mL of ethanol, then shaken again until homogeneous, resulting in a final concentration of 1,000 ppm. To determine the total alkaloid content, 2 mL of the sample is mixed with 2 mL of phosphate buffer at pH 4.7 and 2 mL of Bromocresol Green (BCG) solution. This mixture is then extracted three times with 3 mL of chloroform using a vortex mixer. The chloroform extract is evaporated using a water bath and subsequently redissolved in 10 mL of chloroform. Finally, the absorbance of the solution is measured at the maximum

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wavelength of caffeine using a UV-Vis spectrophotometer at 290 nm.

Determination of Tannin Compounds

The determination of tannin compounds, as described by Noviyanty *et al.* (2020), begins by dissolving 50 mg of extract in distilled water until the total volume reaches 50 mL. This extract solution is then pipetted to obtain concentrations of 100 ppm, 200 ppm, and 300 ppm. To each solution, 1 mL of Folin-Ciocalteu reagent is added, shaken, and allowed to stand for 5 minutes. Then, 2 mL of 15% Na_2CO_3 solution is added, shaken until homogeneous, and allowed to stand for 5 minutes. Distilled water is then added until the total volume reaches 10 mL, and the solution is left to stabilize for the specified time. The absorbance of the extract solution is measured at a wavelength of 765 nm. The concentration is measured three times to ensure consistent results.

Determination of Total Polysaccharides

The determination of total polysaccharides, as described by He *et al.* (2018), begins by dissolving 0.25 mg of extract in distilled water. To each tube, 1 mL of 5% phenol solution is added, and the mixture is shaken until homogeneous. Then, 5 mL of sulfuric acid is added, and the tube is shaken again until the solution is uniform. The measurement is conducted using a UV-Vis spectrophotometer at a wavelength of 488 nm.

Proximate Analysis

Proximate analysis was performed using the SNI 01-2891-1992 standard. According to Yenrina (2015), moisture content was measured using the thermogravimetric method, ash content was determined using the drying ash method, fat content was assessed using the Soxhlet method, protein content was measured using the Kjeldahl method, and fiber content was determined using the Soxhlet method.

Data Analysis

The data analysis results in this study show the outcomes of the phytochemical test, polysaccharide profile, and proximate analysis of *U. lactuca*, which are described descriptively based on comparisons between *U. lactuca* obtained from Ujung Genteng Beach, Sukabumi, West Java, and Batu Layar Beach, Lombok, West Nusa Tenggara. Determination of the absorption curve for the phytochemical test and polysaccharide profile was analyzed using the ANOVA test with a 95% confidence level.

RESULTS AND DISCUSSIONS

Phytochemical Composition Analysis

Determination of Flavonoid Compounds

The absorbance measurement of the quercetin standard curve was conducted using a UV-Vis spectrophotometer at a wavelength of 431 nm. The resulting quercetin standard curve yielded a linear regression equation of $y = 0.1059x – 0.0374$ with a coefficient of determination (R^2) of 0.9976. This result is considered highly reliable, as the correlation coefficient is close to 1, indicating a strong linear relationship. The total flavonoid content was measured using two *U. lactuca* extracts with a UV-Vis spectrophotometer at a wavelength of 431 nm, as presented in Table 2.

Table 2. Total Flavonoid Content.

Sample	Concentration (ppm)	Absorbance	Average Absorbance	Flavonoid Content
Ulva lactuca	100	0.382	0. 381	
Sukabumi	100	0.378		3.95 mg/L
	100	0.383		
Ulva lactuca	100	0.356		
Lombok	100	0.353	0.353	3.686 mg/L
	100	0.351		

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The total flavonoid content obtained from the analysis showed that the highest flavonoid concentration was found in the *U. lactuca* extract from Sukabumi, with an average absorbance of 0.381, while the *U. lactuca* sample from Lombok had an average absorbance of 0.353. The total flavonoid content measured was 3.95 mg/L for *U. lactuca* from Sukabumi and 3.686 mg/L for *U. lactuca* from Lombok. Although the difference is relatively small, it suggests that environmental and geographical factors influence the biosynthesis of secondary metabolites such as flavonoids. These findings are consistent with those of Farasat *et al.* (2014), who reported that flavonoid content in *Ulva* species can reach up to 33.09 mg RE/g dry weight, depending on the species and their habitat. Similarly, research by Garcia-Vaquero *et al.* (2021) demonstrated that seasonal and environmental variations significantly affect the phenolic and flavonoid content in brown macroalgae.

The higher flavonoid levels in *U. lactuca* from Sukabumi may be an adaptive response to more extreme environmental conditions, including greater variations in light intensity and lower temperatures (Pari *et al.*, 2024). In contrast, the waters of Lombok, located in West Nusa Tenggara, are warmer and calmer, with a drier tropical climate. This more stable environment may contribute to differences in flavonoid content in *U. lactuca* from Lombok. Additionally, higher UV radiation due to more intense sunlight exposure could stimulate flavonoid production as a protective mechanism (Agati *et al.,* 2012).

Determination of Alkaloid Compounds

The standard calibration curve measurement for caffeine yielded a linear regression equation of $y = 0.0097x + 0.0066$, with a coefficient of determination (R^2) of 0.9913. Since the R^2 value exceeds 0.99 and is close to 1, it indicates a strong linear relationship. Therefore, the absorbance values obtained for caffeine demonstrate a high degree of linearity. The determination of alkaloid content in two *U. lactuca* samples using a UV-Vis spectrophotometer at a wavelength of 290 nm is presented in Table 3.

Table 3. Total Alkaloid Content.

Sample	Concentration (ppm)	Absorbance	Average Absorbance	Alkaloid Content
Ulva lactuca	200	0.247		
Sukabumi	200	0.248	0.247	24.78 mg/L
	200	0.241		
Ulva lactuca	200	0.262		
Lombok	200	0.265	0.264	26.53 mg/L
	200	0.266		

The determination of alkaloid content was conducted using a UV-Vis spectrophotometer at a wavelength of 290 nm. The highest alkaloid concentration was observed in the *U. lactuca* sample from Lombok, with an average absorbance of 0.264, while the *U. lactuca* sample from Sukabumi had an average absorbance of 0.247. The measured alkaloid content was 26.53 mg/L for *U. lactuca* from Lombok and 24.78 mg/L for *U. lactuca* from Sukabumi. This difference may be attributed to environmental variations such as salinity, water temperature, and exposure to biotic or abiotic stressors, which can stimulate alkaloid biosynthesis as a defense mechanism. Similar trends were reported by El Gamal (2010), who found that alkaloid levels in marine algae are influenced by habitat conditions and ecological pressures. Additionally, genetic divergence between regional populations may contribute to differences in metabolic pathways. These findings align with studies by Plaza *et al.* (2010), which demonstrated species- and location-dependent variations

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in bioactive compound production among macroalgae.

A study by Windyaswari *et al.* (2019) employed *Ulva lactuca* stated it to be positive for containing alkaloids because it is able to react with Mayer (white precipitate) and Dragendorff (orange precipitate). Another study by Alagan *et al.* (2017) utilized methanol extraction and spectrophotometric analysis to measure alkaloid content in *Ulva lactuca*. This study found that the average alkaloid concentration in *Ulva lactuca* was approximately 3 mg/g dry weight.

Determination of Tannin Compounds

The determination of tannin compounds, as measured by the gallic acid standard curve using a UV-Vis spectrophotometer at a wavelength of 765 nm, resulted in a linear regression equation of $y = 0.0454x + 0.1027$, with a coefficient of determination (R^2) of 0.9911. Since the obtained R^2 value exceeds 0.99, the results indicate a strong linear relationship, approaching 1. The tannin content determination using two *U. lactuca* extracts, analyzed with a UV-Vis spectrophotometer at a wavelength of 765 nm, is presented in Table 4.

Table 4. Total Tannin Content.

Sample	Concentration (ppm)	Absorbance	Average Absorbance	Tannin Content
Ulva lactuca Sukabumi	200	0.265	0.263	3.53 mg/L
	200	0.262		
	200	0.264		
Ulva lactuca Lombok	200	0.549	0.551	9.87 mg/L
	200	0.551		
	200	0.555		

The determination of tannin content revealed that *U. lactuca* from Sukabumi had an average absorbance of 0.263, with a tannin concentration of 3.53 mg/L. Meanwhile, *U. lactuca* from Lombok exhibited a higher average absorbance of 0.551, with a tannin content of 9.87 mg/L. These results indicate that the highest tannin concentration was found in the *U. lactuca* sample from Lombok. Recent studies support these findings. For instance, a study by Prasedya *et al.* (2019) reported that ethanol extracts of *U. lactuca* from Lombok waters contained phenolic compounds, including tannins, contributing to strong antioxidant activity (IC_{50} = 53.00 ppm).

Recent studies, such as the one conducted by Pérez-Mayorga *et al.* (2011), have shown that *U. lactuca* contains a relatively high tannin content, ranging from 15 to 25 mg/g dry weight. The extraction method using methanol as a solvent, followed by analysis with the Folin-Ciocalteu spectrophotometric method, has been proven effective in determining tannin content in this alga. A study by Putra *et al.* (2024) further expanded the understanding of the antimicrobial activity of tannins in *U. lactuca*, demonstrating strong effects against various pathogenic bacteria. Additionally, research by Whankatte and Ambhore (2016) highlighted the variability of tannin content in *U. lactuca*, which is influenced by environmental factors such as seasonal changes and sampling location.

Determination of Total Polysaccharides

The measurement results of the anhydrous glucose calibration curve using a UV-Vis spectrophotometer at a wavelength of 488 nm yielded a linear regression equation of $y = 0.0326x + 0.5178$ with a coefficient of determination of 0.997. This result indicates a nearly linear relationship, as the value approaches 1. The polysaccharide content analysis of *U. lactuca* from two different locations, conducted using a UV-Vis spectrophotometer at a wavelength of 488 nm, is presented in Table 5.

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The determination of polysaccharide content in *U. lactuca* extract samples revealed that *U. lactuca* from Sukabumi had an average absorbance of 2.175, corresponding to a polysaccharide concentration of 50.83 mg/L. In comparison, *U. lactuca* from Lombok had an average absorbance of 1.762 and a polysaccharide concentration of 38.165 mg/L. These results indicate that the highest polysaccharide content was found in the *U. lactuca* sample from Sukabumi Beach. Polysaccharides in green macroalgae, particularly ulvans, are known to be highly variable and influenced by external conditions. Recent studies, such as Shalaby and Amin (2019), have shown that seasonal and geographic differences significantly affect the polysaccharide yield and composition in *Ulva* species. Furthermore, Tziveleka *et al.* (2019) highlighted that U. lactuca collected from different coastal regions can vary in polysaccharide content due to environmental adaptation mechanisms.

Table 5. Total Polysaccharides Content.

Sample	Concentration (ppm)	Absorbance	Average Absorbance	Polysaccharides Content
Ulva lactuca Sukabumi	100	2.178	2.175	50.83 mg/L
	100	2.172		
	100	2.175		
Ulva lactuca Lombok	100	1.897	1.762	38.165 mg/L
	100	1.696		
	100	1.693		

A study by Lin *et al.* (2019) reported that the total polysaccharide content in *U. lactuca* ranges from 30% to 40% of its dry weight. Similarly, research conducted by Yu-Qing *et al.* (2016) found that the total polysaccharide content in *U. lactuca* can reach approximately 50% to 60% of its dry weight. Alginate, as one of the main polysaccharides in *U. lactuca*, plays a crucial role in providing texture and stability in various food and pharmaceutical products. Meanwhile, fucoidan, also found in *U. lactuca*, has garnered significant attention due to its diverse biological activities, including antioxidant, antimicrobial, and anti-inflammatory properties.

Proximate Analysis

This study conducted a proximate analysis of seaweed (*U. lactuca*) from two different locations. The results are presented in Table 6. The moisture content of *U. lactuca* from Sukabumi was recorded at 8.53%, while the sample from Lombok had a moisture content of 13.05% (Table 6). These values fall within the typical moisture range of *U. lactuca*, which is approximately 7–18% per 100 grams of net weight. According to research by Garcia-Vaquero *et al.* (2021), variations in moisture content among Ulva species from different regions can affect both biochemical composition and preservation quality.

Table 6. Proximate Analysis.

Parameter (%)	*Ulva lactuca* Sukabumi	*Ulva lactuca* Lombok
Protein	15.47	20.44
Fat	0.22	0.59
Water	8.53	13.05
Ash	33.23	25.79
Carbohydrate	42.55	40.13

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Furthermore, a study by Santhoshkumar *et al.* (2023) noted that seaweeds from warmer, sunnier environments tend to have reduced moisture due to faster dehydration. Recent research by da Costa *et al.* (2018) suggests that high moisture content in *U. lactuca* can affect its shelf life and the quality of the final product. Moreover, a high water content indicates good cell turgor, which is essential for maintaining freshness and texture during consumption.

The ash content of *U. lactuca* from Sukabumi was recorded at 33.23%, while the sample from Lombok had an ash content of 25.79% (Table 6). The results indicate that *U. lactuca* from Sukabumi has a significantly higher ash content compared to the sample from Lombok. *U. lactuca* generally possesses a high ash content, ranging from 20–40% of its dry weight, reflecting its rich mineral composition, including calcium, magnesium, potassium, and iron (Rasyid, 2017). A study by Lin *et al.* (2019) further supports that *U. lactuca* contains significant mineral levels, making it a potential natural mineral supplement. These minerals also provide additional benefits, such as enhancing enzymatic functions and supporting bone health.

The protein content obtained from the proximate analysis showed that *U. lactuca* from Sukabumi contained 15.47%, while the sample from Lombok had a higher protein content of 20.44%. These results indicate that the highest protein concentration was found in *U. lactuca* from Lombok. According to Rasyid (2017), *Ulva* species grown in nutrient-rich waters demonstrate enhanced protein accumulation. Additionally, Lin *et al.* (2019) reported that *U. lactuca* cultivated or harvested in areas with higher anthropogenic input or upwelling events often shows improved protein profiles. The protein levels in both samples fall within the general protein range of *U. lactuca*, which varies between 9 and 27% of dry weight. A study by Sefrienda *et al.* (2023) reported that *U. lactuca* contains approximately 10.8% protein. This protein is rich in essential amino acids, which play a crucial role in protein synthesis in fish.

Proximate analysis of *U. lactuca* from two different locations revealed that the lipid content in the Sukabumi sample was 0.22%, while the Lombok sample had a slightly higher lipid content of 0.59%. The lipid content in *U. lactuca* from Sukabumi is notably low and falls outside the typical range for this species. In general, the lipid content in *U. lactuca* is relatively low, ranging from 0.3% to 5% of dry weight. A study by Kostetsky *et al.* (2018) reported a lipid content of approximately 0.3%. Despite its low concentration, these lipids contain essential fatty acids such as omega-3 and omega-6, which are crucial for cardiovascular health and brain function.

Carbohydrate analysis of *U. lactuca* revealed that the sample from Sukabumi contained 42.55%, while the sample from Lombok had a slightly lower carbohydrate content of 40.13%. These values fall within the typical carbohydrate range for *U. lactuca*. Carbohydrates are the primary component of *U. lactuca*, generally comprising about 20–40% of its dry weight. A study by Yu-Qing *et al.* (2016) reported that carbohydrate content in *U. lactuca* can reach up to 45.1%. These carbohydrates consist of both soluble and insoluble fiber, as well as simple sugars that provide a quick source of energy. Additionally, complex polysaccharides contribute to the texture and stability of food products. *U. lactuca* is also rich in dietary fiber, with levels ranging from 30–35% of dry weight. Research by Shalaby and Amin (2019) highlighted that this fiber includes polysaccharides such as ulvan, which exhibit prebiotic properties and support gut health. Furthermore, dietary fiber aids in regulating cholesterol and blood sugar levels while preventing constipation.

CONCLUSION

The *Ulva lactuca* from Sukabumi exhibits a higher total flavonoid content and polysaccharide levels compared to the sample from Lombok. In contrast, the total

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alkaloid and tannin contents indicate that *U. lactuca* from Lombok has higher concentrations than those from Sukabumi. The nutritional composition of both samples falls within the general range of *U. lactuca*'s nutrient profile, except for the fat content, which was found to be significantly low.

CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this study.

AUTHOR CONTRIBUTION

Nova Lailaturramadhini played a key role in designing the study, coordinating data collection and processing, and drafting the initial manuscript, which was reviewed and revised by Ating Yuniarti, Febriyani Eka Supriatin, and Yunita Maimunah. Damang Suryanto contributed to research materials and data collection. Asep Ridwanudin provided supervision throughout the research. All authors have read and approved the final manuscript.

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