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ANALYSIS OF THE CHEMICAL CHARACTERISTICS OF POWDERED BROTH MADE FROM MULTISPECIES MACROALGAE COLLECTED FROM THE WATERS OF ANYER, BANTEN PROVINCE

Analisis Karakteristik Fisikokimia Kaldu Bubuk Berbasis Makroalga Multispesies dari Perairan Anyer, Provinsi Banten

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ABSTRACT

Seaweed has significant potential to be developed as a raw material for natural powdered broth due to its high nutritional value and abundance of bioactive compounds. This study aimed to analyze the chemical characteristics and consumer acceptability of powdered broth produced from various seaweed species collected from the waters of Anyer. The study employed a completely randomized design (CRD) consisting of four treatments with three replications. The treatments included Gracilaria sp., Ulva lactuca, Kappaphycus alvarezii, and Sargassum sp. The analyzed parameters included NaCl content, moisture content, protein content, fat content, ash content, and hedonic evaluation of appearance, aroma, taste, and texture. Data were analyzed using Analysis of Variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT), while hedonic data were analyzed using the Kruskal–Wallis test followed by the Mann–Whitney test. The results showed that differences in seaweed species had a significant effect ($p < 0.05$) on all evaluated parameters. Based on the effectiveness index analysis using the De Garmo method, powdered broth produced from Ulva lactuca was identified as the best treatment. The product exhibited chemical characteristics consisting of 0.0023% NaCl content, 4.420% moisture content, 16.74% protein content (dw), 1.64% fat content (dw), and 14.3% ash content (dw). The hedonic test scores were 7.50 for appearance (like), 6.67 for aroma (slightly like), 5.97 for taste (neutral), and 6.90 for texture (slightly like).

***Keyword :** Banten; powdered broth; seaweed; Ulva lactuca*

ABSTRAK

Rumput laut memiliki potensi besar untuk dikembangkan sebagai bahan baku kaldu bubuk alami karena kaya akan nutrisi dan senyawa bioaktif. Penelitian ini bertujuan menganalisis karakteristik kimia dan tingkat kesukaan kaldu bubuk berbahan berbagai jenis rumput laut dari perairan Anyer, Banten. Penelitian menggunakan Rancangan Acak Lengkap (RAL) dengan empat perlakuan dan 3 ulangan, dengan perlakuan yaitu *Gracilaria* sp., *Ulva lactuca*, *Kappaphycus alvarezii*, dan *Sargassum* sp. Parameter yang dianalisis meliputi kadar NaCl, air, protein, lemak, abu, serta uji hedonik terhadap kenampakan, aroma, rasa, dan tekstur. Data dianalisis menggunakan ANOVA dan uji lanjut DMRT, sedangkan data hedonik dianalisis menggunakan *Kruskal Wallis* dan *Mann Whitney*. Hasil penelitian menunjukkan bahwa perbedaan jenis rumput laut berpengaruh nyata ($p<0.05$) terhadap seluruh parameter yang diuji. Berdasarkan hasil penelitian, perlakuan terbaik berdasarkan metode indeks efektivitas De Garmo adalah kaldu bubuk

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berbahan rumput laut *Ulva lactuca* dengan nilai karakterisitik kimia NaCl 0.0023%, kadar air 4.420%, kadar protein 16.74 %bk, lemak 1.64 %bk, abu 14.3 %bk dan uji hedonik kenampakan 7.50 (suka), aroma 6.67 (agak suka), rasa 5.97 (netral) dan tekstur 6.90 (agak suka).

Kata Kunci : Banten; kaldu bubuk; rumput laut; *Ulva lactuca*

INTRODUCTION

Seaweed is a fisheries commodity with significant development potential in Indonesia. According to Ambari (2024), this potential is supported by Indonesia's geographical conditions, which include a coastline stretching over 110,000 km and a maritime area of approximately 6.4 million km². These conditions provide a natural habitat for at least 555 of the approximately 8,000 seaweed species found worldwide. One region with abundant seaweed resources is Banten Province, particularly in the waters extending from the southern to the northern areas of the province. Various types of seaweed, such as *Ulva lactuca*, *Gracilaria* sp., *Kappaphycus alvarezii*, and *Sargassum* sp., are widely cultivated and also grow naturally in the region. This abundance makes seaweed utilization in Banten Province highly promising as an economically valuable commodity and a sustainable source of raw materials.

Seaweed is known for its diverse nutritional content and richness in natural bioactive compounds. In general, seaweed contains carbohydrates, proteins, fats, vitamins, and various essential minerals, such as calcium, potassium, phosphorus, sodium, iron, and iodine. Additionally, seaweed contains bioactive compounds, including flavonoids, polyphenols, alkaloids, steroids, saponins, and tannins Soamole *et al.* (2018). The combination of these nutritional components and bioactive compounds gives seaweed significant potential for development in the food industry.

Seaweed can be utilized in the food industry as a raw material for the production of natural powdered broth. Natural powdered broth functions not only as a flavor enhancer but also as a source of nutritional value in food products. To date, powdered broth, whether derived from natural or artificial sources, has been widely used in food preparation. One of the most commonly used artificial flavor enhancers is monosodium glutamate (MSG). Excessive consumption of MSG has been associated with several health complaints, such as nausea, hypertension,

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and type 2 diabetes; however, the relationship between MSG consumption and the occurrence of hypertension and type 2 diabetes still requires stronger scientific evidence and remains a subject of debate. This condition highlights the need for safer and more natural alternatives to powdered broth products. Seaweed has strong potential to serve as such an alternative because green and red seaweeds contain non-essential amino acids, particularly glutamic acid, at concentrations of 12% and 13%, respectively (Kazir *et al.,* 2018), while brown seaweed contains approximately 10.1% glutamic acid (Nazarudin *et al.*, 2021). Furthermore, according to Maulida and Pujilestari (2025), the glutamic acid content of seaweed is not significantly different from that of other commonly used ingredients, such as a combination of mushrooms and vannamei shrimp heads, which contains 3.30% glutamic acid. Glutamic acid is widely recognized as the compound responsible for imparting the umami flavor in food products Dwivedi (2024).

To date, numerous studies on powdered broth have been conducted using various raw materials, such as shrimp shells, fish heads, mushrooms, and small dried shrimp. However, research on the development of seaweed-based powdered broth remains limited, particularly studies utilizing different species of seaweed as raw materials. Therefore, exploring the potential of seaweed as a raw material for natural powdered broth is essential, considering Indonesia's abundant seaweed resources. This study aims to analyze the chemical characteristics and acceptability of powdered broth produced from various species of seaweed.

METHOD

Design, Location, and Time of Study

This study was conducted from February to April 2026 at the Laboratory of Aquatic Product Processing Technology, Sultan Ageng Tirtayasa University, and the Biotech Center Flagship Laboratory, Bogor Agricultural University. The study employed a Completely Randomized Design (CRD) consisting of one factor with three replications. The experimental factor was the variation in seaweed species, which included (P1) *Gracilaria* sp., (P2) *Ulva lactuca*, (P3) *Kappaphycus alvarezii*, and (P4) *Sargassum* sp.

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Equipment and Materials

The equipment used in this study included scissors, a digital balance (SF400), a thin-walled flask, a stove, an oven (Hook), a blender (Daifuku), a basin, a strainer, bowls, a baking tray, porcelain dishes (Pyrex), a desiccator, a furnace (Infitek), a distillation flask, an Erlenmeyer flask, a Kjeldahl flask, a Soxhlet apparatus, High-Performance Liquid Chromatography (HPLC) equipment, fat flasks, burettes, and other supporting laboratory equipment.

The materials used in this study consisted of the seaweeds *Gracilaria* sp., *Sargassum* sp., *Ulva lactuca*, and *Kappaphycus alvarezii*, which were obtained from Anyer. Additional materials included black pepper, red onion, garlic, distilled water, mercuric oxide, H_2SO_4, potassium sulfate, sodium hydroxide, H_3BO_3, hydrochloric acid, K_2CrO_4, and silver nitrate.

Research Procedure

Preparation of Seaweed Powder

The seaweed drying procedure was conducted according to the method described by Herlinawati *et al.* (2022). Fresh seaweed was first sorted to remove damaged or undesirable parts, after which 100 g of seaweed was weighed. The seaweed was then washed under running water and soaked in clean water at a ratio of 1:5 (w/v) for 10 minutes to remove dirt, salt, and other impurities. After the cleaning process, the seaweed was dried in an oven at 60°C for 4 hours until the thallus was completely dry, and subsequently cooled to room temperature. The dried seaweed was then ground using a blender to obtain a fine powder and sieved through a 10-mesh sieve.

Production of Powdered Broth

The production of powdered broth was carried out based on the method described by Herlinawati *et al.* (2022) with several modifications. A total of 50 g of seaweed powder was mixed with 2 g of black pepper, 10 g of red onion, and 10 g of garlic. The mixture was then homogenized using a mixer for 5 minutes until a uniform consistency was obtained. The resulting powdered broth was subsequently packaged in small bottles and tightly sealed prior to the analysis of NaCl content, moisture content, protein content, ash content, fat content, and hedonic quality.

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Analytical Procedures

NaCl Analysis

The production of powdered broth was carried out based on the method described by Herlinawati *et al.* (2022) with several modifications. A total of 50 g of seaweed powder was mixed with 2 g of black pepper, 10 g of red onion, and 10 g of garlic. The mixture was then homogenized using a mixer for 5 minutes until a uniform consistency was obtained. The resulting powdered broth was subsequently packaged in small bottles and tightly sealed prior to the analysis of NaCl content, moisture content, protein content, ash content, fat content, and hedonic quality:

$$\text{NaCl Content (\%)} = \frac{\text{V AgNO3 x N AgNO3 x FP x 58,5}}{\text{Sample Weight}} \times 100$$

Moisture Content Analysis

Moisture content analysis was conducted in accordance with the method described by AOAC (2005). Initially, an empty dish was dried in an oven at 105°C for 15 minutes, cooled in a desiccator for 30 minutes, and subsequently weighed. A 2-g sample was then placed in the dish and heated at 105°C–110°C for 3–4 hours. After drying, the sample was cooled in a desiccator and weighed again. The percentage of moisture content was calculated using the following formula:

$$\text{Moisture content (\%)} = \frac{\text{B1} - \text{B2}}{\text{B}} \times 100\%$$

Ash Content Analysis

Ash content analysis was conducted in accordance with the method described by AOAC (2005). A sample weighing approximately 3–5 g was placed into a porcelain crucible of known weight. The crucible containing the sample was then incinerated in a furnace at 600°C for 4 hours until grayish-white ash was obtained. After the incineration process, the crucible was cooled in a desiccator and subsequently weighed. The percentage of ash content was calculated using the following formula:

$$\text{Ash Content (\%)} = \frac{\text{W1} - \text{W0}}{\text{Sample Weight (gr)}} \times 100\%$$

Protein Content Analysis

Protein content analysis was conducted using the Kjeldahl method according to AOAC (2005), which consists of three stages: digestion, distillation, and titration. A 0.1 g sample was placed into a Kjeldahl flask together with 40 mg HgO, 2.5 mL H_2SO_4, and 1.9 g K_2SO_4. The mixture

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was heated at 430°C for 1–1.5 hours until a clear solution was obtained, and then allowed to cool. The digested sample was subsequently transferred to a distillation apparatus and rinsed 5–6 times with 20 mL of distilled water. Afterward, 20 mL of 40% NaOH solution was added. The distillate (approximately 200 mL) was collected in a 125 mL Erlenmeyer flask containing 4% H_3BO_3 solution and three drops of mixed indicator solution (methyl red–methylene blue, 2:1). Distillation was continued until complete, after which the distillate was titrated with 0.1 N HCl until the solution changed to a purple-red color. The same procedure was performed for the blank sample. Total nitrogen content or percentage of protein was calculated using the following formula:

$$\%N = \frac{(Va-Vb)\ (N\ HCl)\ (14{,}007)}{W \times 1.000} \times 100\%$$

Fat Content Analysis

Fat content analysis was conducted using the Soxhlet extraction method according to AOAC (2005). A 0.5 g sample was wrapped in filter paper and extracted with hexane using a Soxhlet apparatus. The extraction process was carried out under reflux conditions for at least 16 hours. After the extraction process, the solvent was distilled off, and the fat flask was dried in an oven at 105°C for 5 hours. The flask was then cooled in a desiccator for 20–30 minutes and subsequently weighed. The percentage of fat content was calculated using the following formula:

$$\text{Kadar lemak }(\%) = \frac{W3 - W2}{W1} \times 100\%$$

Hedonic Analysis

The hedonic test was conducted in accordance with SNI 2891:1992. The evaluation involved 30 semi-trained panelists consisting of both male and female participants aged 19–23 years. The assessment was carried out subjectively using the hedonic scale scoring method (preference test). The evaluated parameters included taste, appearance, aroma, and texture. The level of preference was measured using a 9-point hedonic scale, ranging from 1 (strongly dislike) to 9 (strongly like).

Optimal Treatment Determination

The optimal treatment for the natural powdered broth samples was determined using the method proposed by De Garmo (1984), as cited in Kartika *et al.* (2025). This method involves assigning weighted values

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to both hedonic and nutritional parameters, including fat, protein, and ash contents. Each parameter was assigned a level of importance using a relative scale ranging from 1 to 7, where 1 indicated "very unimportant" and 7 indicated "very important." The weighting process was based on the objective of developing a natural powdered broth product with high panelist acceptability and optimal nutritional quality. The treatment that achieved the highest overall score across all evaluated parameters was considered the best treatment. The following formulas were used to determine the weighting values, effectiveness scores, and result scores:

$$\text{Weight value} = \frac{\text{Total score of each test parameter}}{\text{Total score of all test parameters}}$$

$$\text{Effectiveness value} = \frac{\text{Treatment value} - \text{Lowest value}}{\text{Highest value} - \text{Lowest value}}$$

Result Value= Weight Value×Effectiveness Value

Data Analysis

The data obtained were analyzed using IBM SPSS Statistics and Microsoft Excel. The data were subjected to Analysis of Variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT) when significant differences among treatments were detected. Data obtained from the hedonic test were analyzed using the Kruskal–Wallis test. If significant differences were observed, the analysis was continued with the Mann–Whitney test as a post hoc analysis.

RESULT AND DISCUSSION

The results of the chemical analysis of powdered broth produced from various seaweed species, including NaCl content, moisture content, protein content, fat content, and ash content, are presented in Table 1. This analysis was conducted to evaluate the effect of different seaweed species on the chemical characteristics of the resulting powdered broth. The analytical data demonstrated variations in the values of each chemical parameter among treatments, indicating that each seaweed species possesses a distinct chemical composition that influences the quality characteristics of the powdered broth produced.

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Table 1. Chemical Parameters of Powdered Broth

Components	*Gracilaria* sp.	*Ulva lactuca*	*Kappaphycus alvarezii*	*Sargassum* sp.
NaCl (%)	0.0040 ± 0.00058[a]	0.0023 ± 0.00117[a]	0.0169 ± 0.00175[b]	0.0040 ± 0.00175[a]
Air (%)	4.193 ± 0.035[a]	4.420 ± 0.187[b]	4.493 ± 0.015[b]	5.52 ± 0.040[c]
Protein (dw) (%)	19.82 ± 0.030[a]	16.74 ± 0.085[b]	8.96 ± 0.040[c]	11.49 ± 0.045[d]
Lemak (dw) (%)	1.36 ± 0.020[a]	1.64 ± 0.018[b]	0.36 ± 0.019[c]	0.67 ± 0.005[d]
Abu (dw) (%)	12.4 ± 0.050[a]	14.3 ± 0.095[b]	18.4 ± 0.120[c]	21.7 ± 0.200[d]

Note: Different letter notations within the same row indicate significant differences at the 0.05 significance level; dw = dry weight

NaCl Content

NaCl (sodium chloride) is a type of table salt composed of Na^+ and Cl^- ions. It is classified as a strong electrolyte and is widely utilized in the food industry Syafruddin and Munawar (2024). The analysis of NaCl content was conducted to determine the salt concentration, which may influence the taste characteristics of the powdered broth. The results of the ANOVA showed that differences in seaweed species used in the powdered broth formulation had a significant effect ($p < 0.05$) on NaCl content, with values ranging from 0.002% to 0.016%. The highest NaCl content was observed in the powdered broth produced from *Kappaphycus alvarezii* at 0.016%, whereas the lowest NaCl content was found in the broth produced from *Ulva lactuca* at 0.002%.

The high NaCl content observed in *Kappaphycus alvarezii* is presumed to be influenced by its physiological characteristics and adaptation to high-salinity waters Erniati *et al.* (2022), which enable the accumulation of minerals both within the tissue and on the thallus surface. This finding is consistent with the study conducted by Agusman and Wibowo (2021), which reported that the thallus of *Kappaphycus alvarezii* contains higher levels of Na and Cl compared to *Gracilaria* sp., which typically grows in waters with lower salinity. Differences in environmental conditions are therefore considered to contribute to variations in mineral composition among seaweed species.

Moisture Content

Moisture content is an important physical characteristic that determines product quality and shelf life. The results of the ANOVA indicated that differences in seaweed species had a significant effect ($p < 0.05$) on the moisture content of the powdered broth products. The moisture content values obtained ranged from 4.9% to

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5.52%, which were lower than the value of 7.12% reported by Herlinawati *et al.* (2022). This difference is presumed to be associated with the longer drying duration applied in the present study, which allowed more optimal water diffusion and evaporation compared to the previous study, where drying was conducted at 60°C for 2 hours.

Based on Table 1, the average moisture content of all treatments complied with the SNI 01-3709-1995 standard, which specifies a maximum moisture content limit of 12%. This result indicates that the powdered broth products produced in this study were of good quality in terms of moisture content. Low moisture content in powdered broth plays an important role in determining product quality and shelf life by inhibiting microbial growth and slowing the chemical reactions that contribute to food deterioration. According to Pasaribu *et al.* (2020), moisture content significantly influences the stability and quality of seaweed-based products during storage.

Ash Content

Ash is an inorganic residue produced from the combustion process, and its content is influenced by the type of raw material, the processing method, and the mineral composition of the material itself Ndumuye *et al.* (2022). The results of this study showed that differences in seaweed species had a significant effect ($p < 0.05$) on the ash content of the powdered broth products. The highest ash content was observed in *Sargassum* sp. at 21.73%, while the lowest ash content was found in *Gracilaria* sp. at 12.48%. These differences indicate variations in mineral composition among the different seaweed species. The high ash content observed in *Sargassum* sp. is presumed to be associated with the abundant inorganic mineral content present in brown seaweed. This finding is consistent with the study conducted by Nurjanah *et al.* (2022), which reported that *Sargassum* sp. contains relatively high levels of minerals, predominantly potassium (K) at 22.20 mg/g, sodium (Na) at 1.65 mg/g, magnesium (Mg) at 11.66 mg/g, and calcium (Ca) at 29.31 mg/g. Furthermore, Erniati *et al.* (2022) stated that brown seaweed generally contains higher levels of potassium and calcium compared to red and green seaweed species.

However, excessively high ash content may adversely affect the quality and applicability of the product in food

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formulations Devi *et al.* (2019). Such conditions can lead to undesirable changes in aroma, taste, and color characteristics of the product. Therefore, ash content must be controlled to ensure that it remains within acceptable limits. Based on the results obtained, all treatments exceeded the quality standard for spice powder established by SNI 01-3709-1995, which specifies a maximum ash content limit of 7%. The high ash content observed in all treatments was likely influenced not only by the drying process but also by the naturally high mineral content present in each seaweed species. Vijay *et al.* (2017) reported that more than 30% of the dry weight of seaweed consists of ash, which contains various minerals, vitamins, and other bioactive compounds..

Protein Content

Protein is a macronutrient composed of amino acid units linked by peptide bonds. In the production of powdered broth, seaweed serves as a source of various nutrients, including protein. The results of the ANOVA indicated that differences in seaweed species had a significant effect ($p < 0.05$) on the protein content of the powdered broth products. According to SNI 01-4273-1996, the minimum protein content required for powdered broth products is 7%. The protein content obtained in this study ranged from 8.9% to 19.8%, indicating that all treatments met the SNI standard requirements. Variations in protein content among treatments were presumed to be associated with differences in the chemical composition of each seaweed species. The protein content of powdered broth produced from *Gracilaria* sp., *Ulva lactuca*, and *Sargassum* sp. was higher than the value reported by Haryanto (2021), who obtained an average protein content of 9.34% in flavoring powder produced from a mixture of *Ulva lactuca* and tuna head extract. The differences in protein content among the treatments are strongly presumed to be influenced by variations in the composition of natural proteins and polysaccharides present in the respective seaweed species, namely *Gracilaria* sp. (6.5%), *Ulva lactuca* (8.7%), and *Sargassum* sp. (7.8%) Rusli *et al.* (2023).

The high protein content observed in *Gracilaria* sp. compared to other seaweed species indicates the presence of favorable environmental conditions, such as optimal light intensity, water temperature, and

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nutrient availability. This phenomenon is closely associated with the availability of nitrogen in the aquatic environment, which plays an important role in protein synthesis. In addition to external environmental factors, the elevated protein content may also be influenced by internal factors, such as harvest age, as seaweed harvested during the active growth phase or under optimal conditions generally contains higher protein levels Purwaningsih (2019). However, the high protein content in *Gracilaria* sp. did not correlate with panelists' preference for the resulting powdered broth product. This was demonstrated by the lower hedonic scores obtained compared to the treatments using *Ulva lactuca* and *Kappaphycus alvarezii*. These findings suggest that sensory acceptance is not determined solely by protein content, but also by the combination of sensory characteristics, including taste, aroma, and other chemical components present in each seaweed species. The protein content of the powdered broth is also closely associated with its glutamic acid content. Glutamic acid is one of the dominant non-essential amino acids present in seaweed proteins and plays a significant role in the formation of umami flavor, thereby enhancing the savory taste of the resulting powdered broth product.

Fat Content

Fat is a macronutrient in food that functions as a source of energy and contributes to the enhancement of savory flavor in powdered broth products Jannah *et al.* (2025). The results of the ANOVA indicated that differences in seaweed species had a significant effect ($p < 0.05$) on the fat content of the powdered broth products, with values ranging from 0.36% to 1.64%. These values tended to be higher than those reported by Haryanto (2021), who obtained fat contents ranging from 0.32% to 0.87% in powdered broth produced from a combination of *Ulva lactuca* and tuna heads. The variation in fat content observed in this study was likely influenced by differences in the natural fat composition of each seaweed species used as raw material. *Gracilaria* sp. contains approximately 1.3% fat Masrikhiyah and Wahyani (2021), *Ulva lactuca* contains 5.17% fat Costa *et al.* (2018), *Kappaphycus alvarezii* contains 0.11% fat Maharany *et al.* (2017), and *Sargassum* sp. contains 0.558% fat Astriani *et al.* (2024). These differences in the fat

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composition of the raw materials contributed significantly to the fat characteristics of the resulting powdered broth products. The average fat content of all treatments complied with SNI 01-4218-1996, which specifies a minimum fat content of 0.3% (w/w). These findings indicate that all powdered broth samples produced in this study met the established SNI standard requirements.

Hedonic Analysis

Based on the results of this study, the average hedonic scores of powdered broth produced from various seaweed species are presented in Table 2.

Table 2. Hedonic Test Results of Seaweed Powdered Broth

Parameters	*Gracilaria* sp.	*Ulva lactuca*	*Kappaphycus alvarezii*	*Sargassum* sp.
Appearance	4.97 ± 1.903^{a}	7.50 ± 0.861^{b}	6.50 ± 1.614^{c}	4.37 ± 1.542^{a}
Aroma	5.90 ± 1.882^{ac}	6.67 ± 1.626^{ab}	7.20 ± 1.562^{b}	5.23 ± 1.924^{c}
Taste	4.90 ± 1.749^{a}	5.97 ± 1.497^{b}	6.00 ± 2.068^{b}	4.77 ± 1.716^{a}
Texture	4.60 ± 1.886^{a}	6.90 ± 1.517^{b}	6.27 ± 1.701^{b}	4.87 ± 1.676^{a}

Note: Different letter notations within the same row indicate significant differences at the 0.05 significance level; 1 (dislike extremely), 2 (dislike very much), 3 (dislike), 4 (slightly dislike), 5 (neutral), 6 (slightly like), 7 (like), 8 (like very much), and 9 (like extremely).

Appearance

Appearance is an important attribute in sensory evaluation, as visual characteristics play a significant role in determining consumer acceptance. The appearance of the powdered broth products is presented in Figure 1.

Figure 1. Appearance of Seaweed Powdered Broth

The results of the Kruskal–Wallis test presented in Table 3 showed that the type of seaweed had a significant effect ($p < 0.05$) on the appearance of the resulting powdered broth products. The average hedonic scores for the appearance parameter ranged from 4.37 to 7.50, corresponding to the categories of "slightly dislike" to "like." Panelists

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showed a greater preference for the treatment using *Ulva lactuca*, which was presumably associated with its finer and more homogeneous powder texture, as well as its visual characteristics that more closely resembled commercial powdered broth products. In contrast, the treatments using *Gracilaria* sp. and *Sargassum* sp. received lower appearance scores due to their coarser and less uniform particle structures. This finding is consistent with the study conducted by Warkey *et al.* (2022), which reported that texture is one of the primary factors influencing appearance assessment, with panelists generally preferring powdered broth products that possess a smooth texture and are free from lumps.

Aroma

Aroma is an important factor influencing consumer acceptance, as sensory perception of aroma can stimulate the perception of palatability even before the product is tasted. The results of the Kruskal–Wallis test presented in Table 2 showed that differences in seaweed species had a significant effect ($p < 0.05$) on the aroma of the resulting powdered broth products, with hedonic scores ranging from 5.23 to 7.20, corresponding to the categories of "neutral" to "like." Further analysis using the Mann–Whitney test indicated that the aroma scores of powdered broth produced from *Ulva lactuca* and *Kappaphycus alvarezii* were not significantly different. This finding is presumably associated with the fresher and more pleasant savory marine aroma of these two seaweed species, making them more familiar and acceptable to the panelists. In contrast, *Sargassum* sp. tended to produce a stronger aroma that was perceived as heavier and excessively natural. These differences are likely attributed to variations in the composition of volatile compounds among the seaweed species. According to Saraswati *et al.* (2019), *Sargassum* sp. contains higher levels of phenolic compounds and phlorotannins compared to red and green seaweed species. During the heating process, these compounds may degrade and form sulfur-containing volatile compounds, which intensify the characteristic aroma of the product Nurjanah *et al.* (2022). This condition is presumed to be one of the factors contributing to the lower aroma scores obtained for the *Sargassum* sp. treatment compared to the other treatments.

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Taste

Taste is one of the primary parameters determining the acceptance of food products, as it strongly influences whether a product is accepted or rejected by consumers Tarwendah (2017). The results of the statistical analysis using the Kruskal–Wallis test showed that variations in seaweed species had a significant effect ($p < 0.05$) on the taste of the powdered broth products, with hedonic scores ranging from 4.77 to 6.00, corresponding to the categories of "slightly dislike" to "slightly like." The highest taste scores were obtained for the powdered broth products produced from *Kappaphycus alvarezii* and *Ulva lactuca*, which did not differ significantly based on the statistical analysis. The higher level of panelist preference for these treatments is presumed to be associated with their more balanced flavor profiles, which are influenced not only by glutamic acid content but also by relatively higher NaCl concentrations compared to the other seaweed species. NaCl contributes to the enhancement of salty taste, which may increase the perception of savory flavor while suppressing bitterness, thereby producing a flavor profile that is more acceptable to panelists Yang *et al.* (2024). In addition, glutamic acid is widely recognized as one of the main compounds responsible for the umami taste in food products Dwivedi (2024).

Texture

Consumer acceptance of a food product can be influenced by texture as one of the determining sensory attributes. The results of the Kruskal–Wallis test presented in Table 2 indicated that variations in seaweed species had a significant effect ($p < 0.05$) on the texture characteristics of the resulting powdered broth products, with hedonic scores ranging from 4.60 to 6.90, corresponding to the categories of "slightly dislike" to "slightly like." The powdered broth products produced from *Ulva lactuca* and *Kappaphycus alvarezii* received the highest texture preference scores and were not significantly different based on the statistical analysis. This finding is presumably associated with their softer, smoother, and easier-to-swallow textures, which provided a more pleasant mouthfeel and did not produce coarse or clumpy sensations during consumption. In contrast, the texture of powdered broth produced from *Gracilaria* sp. tended to be coarser. This

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condition is likely attributed to differences in polysaccharide and fiber composition between *Gracilaria* sp. and *Ulva lactuca*, as well as the influence of the drying and grinding processes, which may have resulted in uneven particle distribution. This finding is consistent with the study conducted by Herlinawati *et al.* (2022), which reported that increasing the concentration of *Gracilaria* sp. in powdered broth formulations reduced the acceptability of texture attributes. This condition is associated with the presence of carrageenan in the seaweed, which functions as a gelling agent.

Determination of the Optimal Treatment

The determination of the optimal treatment for seaweed powdered broth was carried out using the effectiveness index method proposed by De Garmo *et al.* (1984). This method was applied to identify the optimal formulation based on a combination of several quality parameters, including chemical and sensory characteristics. Each parameter was assigned a weighted value according to its relative importance to the quality of the final product, thereby generating an effectiveness value that reflects the overall superiority of each treatment.

Based on the results of the effectiveness index analysis, *Ulva lactuca* achieved the highest effectiveness value of 0.856 and was therefore identified as the optimal treatment. This high effectiveness value indicates that the use of *Ulva lactuca* was able to produce powdered broth with superior quality in terms of both chemical characteristics and panelist acceptance. In contrast, the treatments using *Gracilaria* sp., *Kappaphycus alvarezii*, and *Sargassum* sp. produced lower effectiveness values, indicating that the quality of the resulting products was less optimal compared to the powdered broth produced from *Ulva lactuca*.

CONCLUSION

The type of seaweed used had a significant effect ($p < 0.05$) on both the chemical characteristics and acceptability of the resulting powdered broth products. Based on the effectiveness index analysis using the De Garmo method, *Ulva lactuca* was identified as the best formulation because it exhibited a balanced combination of favorable chemical characteristics and relatively higher sensory acceptance compared to the other treatments. The

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chemical characteristics of the powdered broth produced from *Ulva lactuca* were as follows: NaCl content of 0.0023 ± 0.00117%, moisture content of 4.420 ± 0.187%, protein content of 16.74 ± 0.085%, fat content of 1.64 ± 0.18%, and ash content of 14.3 ± 0.095%. The hedonic test scores were 7.50 ± 0.861 for appearance ("like"), 6.67 ± 1.626 for aroma ("slightly like"), 5.97 ± 1.497 for taste ("neutral"), and 6.90 ± 1.517 for texture ("slightly like"). These findings indicate that *Ulva lactuca* has strong potential to be developed as an alternative raw material for natural flavor enhancers in powdered broth products, particularly for producing savory flavor characteristics preferred by consumers. Furthermore, the utilization of this seaweed species may contribute to the diversification of value-added fishery products while supporting the sustainable utilization of local marine resources.

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