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Comparative Nutritional Composition and Sensory Acceptability of Dried *Kappaphycus alvarezii* Processed by Limewater and Rice-Water Soaking

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ABSTRACT

Kappaphycus alvarezii is an economically important red seaweed with potential for development into convenient food products, although postharvest soaking and drying can modify its nutritional and sensory characteristics. This study compared the proximate composition and sensory acceptance of dried, unsalted K. alvarezii prepared using limewater (A) or rice-water (B) soaking. Processing was undertaken at CV LARS, Makassar, during July–August 2025. Proximate determinations were conducted at Politeknik Pertanian Negeri Pangkep, while 30 panelists assessed appearance, aroma and texture using a five-point hedonic scale at Institut Teknologi dan Bisnis Maritim Balik Diwa. Each processing treatment was prepared in three repetitions. Limewater-treated samples contained 17.56% moisture, 14.60% ash, 4.02% crude protein, 0.42% lipid and 63.37% carbohydrate; corresponding rice-water values were 16.06%, 13.60%, 7.14%, 0.45% and 62.76%. Thus, rice-water processing produced a higher measured crude-protein proportion, whereas limewater processing yielded slightly higher ash and carbohydrate values. Dry presentations of both treatments received approximately 4.0 for appearance; the highest reported texture score was 3.7 for the rehydrated limewater sample. Aroma scores were generally 3.4–3.6. These findings indicate that both methods can produce acceptable seaweed products with distinct nutritional and sensory characteristics. Because individual replicate observations and complete inferential statistics were unavailable, the observed differences should not be interpreted as independently verified significant effects. Further work should assess microbiological safety, water activity and storage stability.

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INTRODUCTION

Seaweeds have become increasingly important as both traditional foods and emerging raw materials for diversified, sustainable food systems. Their appeal derives from relatively rapid biomass production, cultivation without arable land, and the presence of polysaccharides, minerals and other compounds relevant to food processing. Their nutritional quality is nevertheless heterogeneous, varying with species, cultivation environment and postharvest conditions. Reviews of algal foods emphasize the need to evaluate individual products rather than assuming that all seaweeds provide the same nutrient concentrations or physiological benefits (Wells et al., 2017; Holdt & Kraan, 2011). The economic promise of edible macroalgae is especially relevant in coastal regions, where processing at small and medium enterprises can connect aquaculture production with locally marketed food products. Establishing simple, repeatable handling methods is therefore a practical priority for developing seaweed-based foods with desirable composition and consumer acceptance.

Among cultivated tropical red algae, Kappaphycus alvarezii is notable for its importance as a source of kappa-carrageenan, a sulfated polysaccharide widely used in

food formulations. Its conventional industrial value has encouraged production, but the entire biomass can also be considered for food ingredients and minimally processed products. The chemistry and organization of its carrageenan-rich tissues influence hydration, viscosity, gel formation and texture during processing (Carrageenan From Kappaphycus alvarezii, 2022). A broader review of food applications highlights opportunities to incorporate K. alvarezii into snacks, cereal products and other foods, although preparation techniques must be adapted to achieve acceptable sensory properties (Ridhwan et al., 2024). Such applications can diversify the value derived from coastal seaweed farming, provided the chosen processing conditions maintain both product quality and the suitability of the final material for consumption.

South Sulawesi provides an important setting for examining practical seaweed processing because coastal communities participate in farming, drying, trading and further conversion of carrageenophyte biomass. Product upgrading does not necessarily require sophisticated extraction equipment. Washing, soaking, drying and rehydration can produce a convenient ingredient for household preparation or further manufacturing. However, these simple steps expose the biomass to prolonged contact with water, dissolved salts and changes in temperature and pH. They may modify the measured composition even when no nutrients are deliberately added. Such effects are important to characterize before recommending a preparation protocol for wider adoption. Research on K. alvarezii has shown that postharvest processing can influence biochemical characteristics and the quality of resulting ingredients (Nunes et al., 2024; Comparative Study of Drying Methods, 2016).

The nutritional characterization of dried seaweed often begins with proximate analysis, which reports moisture, ash, crude protein, crude lipid and carbohydrate or nitrogen-free extract. These measures offer a useful first description, but they are operational quantities rather than complete indicators of physiological value. In seaweed, carbohydrate includes substantial fractions of structural and soluble polysaccharides, while crude protein is frequently derived from nitrogen measurements and a conversion factor that may not fully reflect true protein. Studies comparing tropical eucheumatoids indicate pronounced differences in ash and carbohydrate fractions, alongside relatively modest crude protein and lipid concentrations (Chemistry of Tropical Eucheumatoids, 2021). Reviews of seaweed proteins similarly distinguish protein content from amino acid quality, digestibility and extraction potential (Seaweed Proteins, 2024; Seaweed Proteins Are Nutritionally Valuable, 2022). Accordingly, proximate findings are most informative when interpreted with reference to processing conditions and analytical limitations.

Moisture is a particularly consequential variable because it affects product mass, the proportion of other constituents expressed on a wet-weight basis, and microbial stability. Drying is used to reduce water content and facilitate transport and storage, yet the final moisture level depends on pretreatment, material thickness, climate, drying duration and method. A comparison of oven, sun, vacuum and freeze drying of Malaysian red seaweed demonstrated that processing can alter chemical constituents (Comparative Study of Drying Methods, 2016). More recently, Nunes et al. (2024) examined drying protocols in K. alvarezii and found that processing conditions influenced bioactive compounds and related activities. Measured moisture alone does not establish shelf life, because microbial proliferation depends also on water activity, packaging, initial contamination and storage conditions. This distinction is especially relevant for products marketed as ready-to-prepare or ready-to-eat foods.

Ash is often interpreted as an approximate measure of total inorganic residue, but it does not identify particular minerals or confirm that all minerals are nutritionally available. Seaweed can accumulate mineral elements from seawater, making ash concentrations sensitive to growth location, washing and contact with processing water. Analytical work on K. alvarezii and related tropical species has documented considerable variation in ash and trace elements, reinforcing the need to evaluate the harvested material and its processing history (Chemistry of Tropical Eucheumatoids, 2021). Soaking could remove surface salts and soluble ions, whereas alkaline conditions could alter tissue chemistry and mineral interactions. The direction and magnitude of such effects cannot be determined without paired analysis of soaking solutions and residual biomass. As a result, modest differences in ash should be described as compositional observations, not definitive evidence of improved mineral nutrition.

Protein is another component of interest, particularly as seaweed is increasingly investigated for use in formulated foods. Nevertheless, K. alvarezii is mainly cultivated for hydrocolloids rather than for high protein yield. Studies of its nutritional composition show that crude protein is highly dependent on environmental conditions and the analytical basis of reporting (Seasonal Variation, 2015). The broader literature identifies seaweed proteins as potentially useful food ingredients but cautions that nutritional value depends on amino acid profiles and digestion, not crude nitrogen concentration alone (Seaweed Proteins Are Nutritionally Valuable, 2022). A difference in measured crude protein between two dried products may also result from dilution or concentration effects involving other components. Consequently, a process yielding higher crude-protein percentage should be considered promising, while claims of enhanced protein retention require mass-balance data and standardized dry-weight comparisons.

Carbohydrate is a major fraction of K. alvarezii biomass, largely owing to its carrageenan-rich matrix and other structural constituents. Carrageenan forms the basis of many applications in food texture management, but total carbohydrate determined analytically may also include different saccharide classes that have distinct physiological functions. Processing practices that modify hydration, ionic conditions and thermal exposure may influence the arrangement and extraction behavior of polysaccharides (Carrageenan From Kappaphycus alvarezii, 2022). Research on advanced carrageenan extraction has additionally demonstrated that treatment conditions influence physicochemical properties and fractionation (Advanced Extraction Techniques, 2024). It is therefore appropriate to discuss total carbohydrate as a broad compositional indicator rather than equating the measured percentage with purified carrageenan or dietary fiber. Further analytical work would be needed to separate these components and assess their contribution to product functionality.

Soaking is attractive for small enterprises because it is accessible, inexpensive and easy to combine with natural drying. Limewater and rice water represent two contrasting processing media. Limewater creates an alkaline, calcium-containing environment, potentially influencing ion exchange and the behavior of sulfated polysaccharides. Rice water contains dispersed or soluble rice-derived constituents, but its exact composition varies according to preparation. Both processes can change the appearance and tactile properties of hydrated algae, particularly when combined with repeated washing and drying. Available evidence about alkaline processing and carrageenan chemistry provides a mechanistic context, but not proof of the specific responses of products prepared with household limewater or rice water (Carrageenan

From Kappaphycus alvarezii, 2022; Advanced Extraction Techniques, 2024). Direct comparative examination of both methods is consequently important for selecting simple protocols under actual local processing conditions.

Sensory quality is as important as nutrient composition when developing a seaweed product for consumers. Appearance influences initial expectations, whereas aroma and texture shape the experience of consumption. Seaweed products may display marine odors, variable color and a texture that shifts substantially when dried material is rehydrated. A systematic assessment of sensory research concluded that postharvest interventions, including drying and cooking, affect sensory attributes and that preferences are strongly dependent on product context (Sensory Evaluation of Seaweed, 2025). Consumer research also indicates that familiarity and neophobia can influence willingness to accept foods containing seaweed (Neophobia and Seaweed Consumption, 2021). Sensory evaluation is therefore necessary even when a product appears nutritionally suitable, because an analytically favorable formulation may still be poorly accepted.

The physical state of a sample should be considered explicitly in sensory comparisons. A dried seaweed sample may have a visually uniform color and firm appearance, while rehydration can soften tissues and modify their surface gloss, odor release and chewiness. These responses are expected to interact with the chemical and structural changes induced by soaking. Food-product research using K. alvarezii flour has demonstrated that pretreatment affects the physical behavior of rice-based snacks and dough systems (Kappaphycus alvarezii Flours, 2023). Evidence from other edible seaweeds also shows that processing and salting can alter sensory acceptability (Effect of Dry Salting, 2024). Nevertheless, findings from other species or processed food matrices cannot be transferred without qualification to dried, unsalted K. alvarezii. Evaluating the same biomass in both dry and hydrated presentations can help distinguish visual preference from texture preference during intended use.

The present study compared the proximate composition and sensory acceptance of dried, unsalted K. alvarezii produced through limewater and rice-water soaking at CV LARS in Makassar, Indonesia. The nutritional comparison focused on moisture, ash, crude protein, lipid and carbohydrate, while a 30-person hedonic panel evaluated appearance, aroma and texture of dried and rehydrated presentations. The study sought to identify practical differences between two locally applicable preparation routes and to provide preliminary evidence for development of value-added seaweed foods. Because process effects can depend on raw-material variability, reporting basis and sampling structure, interpretation was confined to the measured values and the extent of available statistical documentation. The resulting evidence can guide improved processing trials and highlight which additional safety and quality assessments should precede commercial recommendations.

METHODS

The study was performed in July–August 2025. Kappaphycus alvarezii processing was conducted at CV LARS, Makassar, South Sulawesi, Indonesia. Nutritional assays were performed at the Processing Biochemistry Laboratory, Politeknik Pertanian Negeri Pangkep, and sensory evaluations at the Fishery Product Processing Laboratory, Institut Teknologi dan Bisnis Maritim Balik Diwa. The study compared two soaking treatments, each prepared in three repetitions: treatment A, limewater soaking; and treatment B, rice-water soaking. For treatment A, seaweed was immersed in a freshwater mixture

containing 30% salt at a reported seaweed-to-water ratio of 1:20 and a water-to-limestone ratio of 2:1, soaked for 2 h, sun-dried, then soaked in freshwater for 4 h with hourly water changes. The material was dried again and packed in 35-g portions. Because the descriptions of the salt percentage and limestone ratio do not specify concentration basis or reagent form, they should be confirmed against the original production log before replication. For treatment B, washed and drained seaweed was placed in rice water made by blending rice and mixing it with water. Three approximately 6-h soaking and drying cycles were undertaken, followed by a final wash and drying. The sample preparation reflects the importance of drying and pretreatment in the physical and nutritional behavior of K. alvarezii (Nunes et al., 2024; Comparative Study of Drying Methods, 2016; Kappaphycus alvarezii Flours, 2023; Rudke et al., 2022).

Proximate analyses assessed moisture, ash, crude protein, lipid and carbohydrate in triplicate processing batches. The initial protocol described gravimetric moisture measurement after drying, ash determination after high-temperature incineration, nitrogen-based protein estimation, solvent lipid extraction and carbohydrate analysis according to a Luff–Schoorl-type sugar method; the exact analytical standard, protein conversion factor and carbohydrate calculation require confirmation from laboratory records. The percentages are presented as supplied, without claiming a verified dry-matter basis (Chemistry of Tropical Eucheumatoids, 2021; Seasonal Variation, 2015; Seaweed Proteins Are Nutritionally Valuable, 2022). A five-point hedonic test was conducted with 30 panelists, assigning 1 = strongly dislike, 2 = dislike, 3 = neither like nor dislike, 4 = like and 5 = strongly like. Dried and rehydrated products were assessed for appearance, aroma and texture, yielding four sensory presentations: A1 (dry limewater), A2 (rehydrated limewater), B1 (dry rice water) and B2 (rehydrated rice water). The approach follows the distinction between sensory response and analytical composition emphasized in seaweed studies (Sensory Evaluation of Seaweed, 2025; Neophobia and Seaweed Consumption, 2021). The original protocol referred to independent-samples testing and ANOVA at a 5% significance level, but replicate-level and panelist-level datasets and complete test outputs were not available for this manuscript; therefore no new p-values or inferential conclusions were generated.

RESULTS AND DISCUSSION

The addition of papain and bromelain was associated with different mineral concentration patterns in anchovy fish sauce (Table 1). The untreated control had the highest calcium concentration (0.116%), papain treatment had the highest sodium concentration (48.502 ppm), and bromelain treatment had the highest iron concentration (34.617 ppm). Relative to the control, both enzyme-treated samples contained less calcium. Sodium increased slightly following papain treatment but decreased following bromelain treatment, while iron increased marginally under bromelain and decreased under papain. These differences describe the recorded treatment means only; whether they are statistically reliable cannot be determined without replicate measurements and statistical testing.

The two processing methods produced different numerical proximate profiles (Table 1). Rice-water treatment B had lower measured moisture and ash and higher crude protein and lipid than limewater treatment A. The absolute differences were relatively small for moisture, ash, lipid and carbohydrate but greater for protein. As full replicate-level observations and statistical outputs were not provided, these patterns are

interpreted descriptively rather than as confirmed statistically significant processing effects.

Table 1.
Proximate composition of Kappaphycus alvarezii after two soaking treatments (%)

Treatment	Moisture	Ash	Crude protein	Lipid	Carbohydrate
A: Limewater	17.56	14.60	4.02	0.42	63.37
B: Rice water	16.06	13.60	7.14	0.45	62.76

Moisture content

Moisture was 17.56% in the limewater sample and 16.06% in the rice-water sample, a difference of 1.50 percentage points. Such a difference could reflect water-holding characteristics, duration of the final drying step, environmental conditions or differences in the tissue matrix after soaking. Repeated rice-water soaking did not result in a higher final moisture percentage in the supplied samples. Seaweed drying studies have shown that processing conditions influence both residual water and biochemical quality (Nunes et al., 2024; Comparative Study of Drying Methods, 2016). Nevertheless, lower measured moisture should not be equated with demonstrated microbial safety or extended shelf life. Water activity, microbial counts and packaging performance were not measured, and further storage trials are necessary before making preservation claims.

Ash content

Ash reached 14.60% in A and 13.60% in B. The one-percentage-point difference may be related to differences in soluble mineral removal, contact with calcium-containing processing media or initial biomass variability. Kappaphycus species are known to contain substantial mineral fractions, and the concentration of specific elements varies with environmental and processing factors (Chemistry of Tropical Eucheumatoids, 2021; Seasonal Variation, 2015). Limewater contact provides a plausible source of calcium-related interactions, but the present assay measured only total ash. Consequently, the higher ash proportion cannot be interpreted as proof of greater calcium content or superior mineral bioavailability. Direct elemental analysis of the processed seaweed and the discarded soaking water would be required to test those hypotheses.

Crude protein content

The most pronounced numerical contrast was observed for crude protein: 4.02% in treatment A and 7.14% in treatment B, corresponding to a 3.12-percentage-point difference. Rice-water processing thus resulted in a higher measured protein percentage in these samples. The values are broadly plausible for Kappaphycus biomass, which generally has more modest protein content than several other edible seaweeds (Chemistry of Tropical Eucheumatoids, 2021; Seaweed Proteins, 2024). The result should not, however, be interpreted as evidence that the rice water synthesized protein within the algae. Possible explanations include differences in leaching of nonprotein soluble components, changes in nitrogen retention, analytical variability or compositional concentration effects. Since crude protein may be calculated from total nitrogen, seaweed-specific conversion factors and nonprotein nitrogen are also relevant (Seaweed Proteins Are Nutritionally Valuable, 2022). Verification requires consistent dry-matter reporting, replicated raw assay outputs and, ideally, amino acid profiling or a mass-balance assessment. The supplied source text describes the protein difference as

statistically significant, but the accompanying inferential outputs were not provided for independent verification.

Lipid content

Both treatments yielded low lipid values, with 0.42% for A and 0.45% for B. The difference was only 0.03 percentage points and is unlikely to be nutritionally important without additional evidence. Low crude lipid is characteristic of the carrageenan-rich composition of this red alga, as observed in chemical studies of tropical eucheumatoids (Chemistry of Tropical Eucheumatoids, 2021). Since the amount of fat was not measured on an absolute mass-balance basis before and after processing, the slightly higher percentage in B cannot demonstrate lipid enrichment. These results suggest that either procedure maintained the usual low-fat profile of the material, while more discriminating lipid-characterization methods would be required to examine fatty acid composition.

Carbohydrate content

Carbohydrate was 63.37% after limewater processing and 62.76% after rice-water processing, a difference of 0.61 percentage points. This dominant fraction is consistent with the polysaccharide-rich nature of K. alvarezii and its importance in carrageenan production (Carrageenan From Kappaphycus alvarezii, 2022; Advanced Extraction Techniques, 2024). The small difference could arise from soluble-solid removal or proportional changes in other proximate fractions. Importantly, the analytical description refers to a sugar-based Luff–Schoorl method, whereas the reported components sum to approximately 100%, which may instead indicate carbohydrate calculated by difference. The analytical report should clarify this point. Neither method establishes the proportions of carrageenan, dietary fiber and digestible sugars without further assays. Thus, the total carbohydrate percentages should not be presented as a direct measurement of carrageenan yield or functional fiber.

Sensory acceptability

Thirty panelists assessed appearance, aroma and texture of dry (A1, B1) and rehydrated (A2, B2) presentations on a five-point scale. The source material supplies selected mean scores and a narrow range for aroma, rather than complete records for all 12 treatment-by-attribute combinations. The defensible observations are summarized in Table 2 without filling missing values. Both dry presentations received a mean appearance score around 4.0, corresponding to "like." Rehydrated A2 received an appearance score of 3.9, compared with 3.7 for B2. The highest reported texture score was 3.7 in A2. Reported aroma scores lay approximately between 3.4 and 3.6, suggesting moderate liking rather than a clear superiority of one method.

Table 2. Available reported hedonic observations for dried and rehydrated presentations

Presentation	Appearance	Aroma	Texture
A1: Limewater, dry	4.0	Not specified individually	Not specified
B1: Rice water, dry	4.0	Not specified individually	Not specified
A2: Limewater, rehydrated	3.9	Not specified individually	3.7
B2: Rice water, rehydrated	3.7	Not specified individually	Not specified

The appearance advantage for dried samples could be related to visual uniformity, reduced surface moisture and the presentation of seaweed tissue after dehydration. A2's comparatively favorable texture is consistent with hydration and potential interactions between calcium-containing water and the polysaccharide-rich structure of Kappaphycus, although texture mechanisms were not directly tested (Carrageenan From Kappaphycus alvarezii, 2022). Sensory research consistently shows that processing, product format and familiarity affect seaweed liking (Sensory Evaluation of Seaweed, 2025; Neophobia and Seaweed Consumption, 2021). Other seaweed processing studies similarly demonstrate that preparation conditions can influence preference, but findings depend on the species and food matrix (Effect of Dry Salting, 2024; Kappaphycus alvarezii Flours, 2023). Because the same panelists may have evaluated all four products, a repeated-measures or appropriately blocked analysis may be preferable to a simple independent-samples test. Without the underlying individual scores it is not possible to determine whether apparent differences are statistically distinguishable.

Overall, the two processes presented a tradeoff rather than a single universal winner. Rice-water treatment produced the higher observed crude-protein percentage and slightly lower moisture, whereas limewater treatment delivered the strongest reported texture preference after rehydration and slightly higher ash and carbohydrate percentages. Both methods generated dried products whose appearance was liked. Practical selection should take account of process duration, reproducibility, chemical purity of any lime used, washing-water quality, sensory preference and the intended end use. Future evaluations should quantify moisture activity, sodium and calcium, microbial safety, potential contaminants, sensory variability and storage behavior. Processing claims should be supported by replicate-level statistical analysis, clearly standardized reporting bases and accurate descriptions of reagent concentrations.

CONCLUSION

Two locally applicable soaking methods produced dried, unsalted Kappaphycus alvarezii with distinct proximate profiles and generally acceptable sensory characteristics. The limewater method yielded 17.56% moisture, 14.60% ash, 4.02% crude protein, 0.42% lipid and 63.37% carbohydrate, whereas rice-water soaking yielded 16.06%, 13.60%, 7.14%, 0.45% and 62.76%, respectively. Rice-water processing therefore gave a higher measured crude-protein proportion and somewhat lower moisture and ash, while both methods retained the characteristic carbohydrate-rich, low-lipid profile of this seaweed. Thirty panelists rated the appearance of both dry products at approximately 4.0 on a five-point hedonic scale. The highest reported rehydrated texture score, 3.7, occurred with limewater processing, suggesting a potential advantage when the product is consumed after soaking. Aroma scores were broadly similar across presentations. These results support both processing approaches as candidates for developing value-added seaweed foods, but they do not establish that one method is superior across every quality criterion. Complete replicate data and sensory responses are required to validate statistical differences. Further work should standardize treatment concentrations and drying conditions, clarify carbohydrate determination, and evaluate water activity, microbial quality, mineral composition, and shelf life before any commercial safety or nutritional claims are made.

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