

FORTIFICATION OF RED SEAWEED (*Kappaphycus alvarezii*) FLOUR IN SNACK BAR FORMULATION AS AN EVALUATION OF IODINE CONTENT AND TEXTURE IMPROVEMENT

Fortifikasi Tepung Rumput Laut Merah *Kappaphycus pavarezii* Pada Formulasi *Snack Bar* Sebagai Evaluasi Kandungan Yodium dan Peningkatan Tekstur

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ABSTRACT

Consumer interest in practical, nutrient-dense functional foods has prompted the development of healthy snack alternatives from local raw materials. The red seaweed *Kappaphycus alvarezii* shows promise as a fortifying ingredient, not only for its iodine content and physical texture, but also its moisture profile and overall influence on the snack bar's sensory traits. To evaluate this potential, a completely randomized design was set up across four treatments—a seaweed-free control, and three others fortified with seaweed flour at 10%, 20%, and 30%. The evaluation parameters covered moisture, iodine, hardness, and a hedonic sensory test with 25 semi-trained panelists. Chemical and texture data were subjected to ANOVA followed by Duncan's test, while sensory scores underwent Kruskal-Wallis and Dunn's analyses. Our findings revealed that the 30% level produced the highest iodine reading, at 60.93 µg/g. Moisture content dropped sharply ($p < 0.05$) from 17.53% in the control to 12.53% in the 30% treatment—although this still slightly exceeds the 11.26% cap set by SNI 01-4216-1996. Hardness readings ranged from 4333.74 to 4588.68 gf, which falls well within the typical span of commercial snack bars. In terms of sensory response, seaweed inclusion markedly affected color, aroma, and texture, but did not significantly alter taste scores. Overall, the 10% seaweed formulation stood out as the best, yielding higher iodine than the control, maintaining an acceptable mouthfeel, and earning the highest panelist preference. Taken together, these results position this particular formulation as a viable candidate for a functional food product aimed specifically at boosting dietary iodine intake.

Keywords: Iodine Content, *Kappaphycus alvarezii*, Moisture Content, Seaweed Flour, *Snack Bar*, Texture.

ABSTRAK

Kebutuhan pangan fungsional yang praktis dan bergizi mendorong pengembangan produk camilan sehat berbasis bahan lokal. Rumput laut merah *Kappaphycus alvarezii* berpotensi digunakan sebagai bahan fortifikasi karena kandungan yodium, kekerasan, kadar air, dan karakteristik organoleptik *snack bar* yang dihasilkan. Rancangan penelitian yang digunakan adalah rancangan acak lengkap dengan empat perlakuan, yaitu tanpa tepung rumput laut (kontrol), dan fortifikasi tepung rumput dengan konsentrasi 10%, 20% dan 30%. Parameter yang diuji yaitu kadar air, kadar yodium, kekerasan, dan uji organoleptik hedonik yang melibatkan 25 panelis semi terlatih. Analisis data menggunakan ANOVA - *Duncan* untuk data kimia dan tekstur, serta uji *Kruskal-Wallis - Dunn* untuk data organoleptik. Hasil penelitian menunjukkan bahwa penambahan rumput laut meningkatkan kadar yodium hingga 60,93 µg/g pada perlakuan tepung rumput laut 30%. Kadar air *snack bar* menurun signifikan ($p < 0,05$) dari 17,53% perlakuan kontrol menjadi 12,53% dengan penambahan tepung rumput laut 30%, meskipun belum memenuhi SNI 01-4216-1996 dengan nilai maksimal 11,26%. Tekstur kekerasan pada *snack bar* berkisar antara 4333,74-4588,68 gf dan masih berada di rentang *snack bar* komersil. Pada warna, aroma, dan tekstur nilai-nilai dipengaruhi penambahan tepung rumput laut *kecuali* rasa. Formula yang diberikan tepung rumput laut 10% merupakan formulasi terbaik dengan kadar yodium lebih tinggi dari pada kontrol, tekstur dapat diterima, dan tingkat kesukaan panelis tertinggi, sehingga berpotensi dikembangkan sebagai pangan fungsional sumber yodium.

Kata kunci: Kadar Air, *Kappaphycus alvarezii*, Kadar Yodium, *Snack Bar*, Tekstur Tepung Rumput Laut

INTRODUCTION

Iodine is an essential mineral required by the body in small amounts to synthesize the hormones thyroxine (T4) and triiodothyronine (T3), which are crucial for normal growth as well as physical and mental development in humans (Astuti *et al.*, 2024). The daily iodine intake requirement is approximately 150 µg/day (Indonesian Ministry of Health, 2024). Iodine deficiency can lead to various serious consequences, such as goiter, endemic cretinism, hearing impairment, growth disorders, and even increased neonatal mortality rates (Anggarawati, 2023).

One of the best natural sources of iodine is seaweed; its iodine content can be 2,400 to 155,000 times higher than that of land-based vegetables (Mongi *et al.*, 2019). Certain seaweeds are particularly rich in iodine; for instance, *Kappaphycus alvarezii* contains up to 9 µg/g, compared to 7.66 µg/g in *Sargassum polycystum* and 4.78 µg/g in *Caulerpa lentifera* (Djamaludin *et al.*, 2024). In addition to iodine, *K. alvarezii* is rich in carbohydrates (39–51%), protein (17.2–27.13%), essential fatty acids, minerals (K, Ca, P, Na, Fe, I), vitamins (A, B1, B2, B6, B12, C), and various enzymes (Datunsolang *et al.*, 2020). This high iodine content is believed to be the reason for the low prevalence of goiter in Japan affecting only 1 in approximately 1 million people compared to Indonesia, where the prevalence is around 8 per 100 people, or approximately 8% (Mongi *et al.*, 2019).

Fortifying food products with *K. alvarezii* flour is one strategy for preventing Iodine Deficiency Disorders (IDD). Research indicates that increasing the fortification of red seaweed flour can significantly raise iodine levels in processed products (Sulistiyati & Siahaan, 2022). However, *K. alvarezii* flour possesses gelling properties that can affect product texture; specifically, high-concentration additions tend to result in a harder and more brittle texture

(Lobo *et al.*, 2019). Diversifying seaweed flour into snack bars holds potential, as these products are convenient, popular across various demographics, and have evolved into functional foods (Fanny *et al.*, 2020). Nevertheless, research on the use of *K. alvarezii* seaweed flour as an iodine source in snack bar formulations remains limited; therefore, further study is required to evaluate the iodine content and textural characteristics of the resulting products.

RESEARCH METHODS

Research Site and Time

This research was conducted from September 2025 to May 2026. The snack bar production process, as well as physical, moisture content, and organoleptic testing, were carried out at the Integrated Maritime Laboratory, Faculty of Marine and Fisheries Technology. Iodine content testing was performed at the Center for Quality Assurance and Fishery Product Diversification (BPPMDPPP) in Gorontalo City.

Tools and Materials

The tools used in this research were digital scales, Miyako BL-101 blender, 60 mesh sieve, knife, container, stove, frying pan, Fomac Bov-MT90 brand oven, 20 x 10 cm mold, baking paper, gloves, spatula and spoon.

The ingredients used in this research were dried red seaweed taken from Popalo Village, Kwandang Regency, oats, almonds, pumpkin seeds, flax seeds, raisins, honey, brown sugar, water and wheat flour.

Research Procedure

The research was conducted in two stages: a preliminary study and a main study. The initial stage involved producing red seaweed (*K. alvarezii*) flour, following the method of Giovani *et al.* (2023). Dried seaweed was thoroughly washed and then soaked in rice-rinsing water for 24 hours to reduce its fishy odor and soften the stems. After rinsing, the seaweed was ground using a meat grinder (Maksindo) to accelerate drying, then dried in an oven (Kl OVN-03) at 70°C for two days. The dried seaweed was subsequently pulverized in a blender (Miyako BL-101) and sieved to obtain a fine flour. The snack bar production process followed a modified version of the method described by Auliarsi (2023). In the first stage, oats, almonds, and pumpkin seeds were roasted for 5 minutes and then coarsely blended. In the second stage, flaxseeds and raisins were boiled for 5 minutes, and palm sugar was melted. In the third stage, the flour according to the specific treatment (F1, F2, F3) was weighed and mixed with all other ingredients until the mixture was uniform. In the fourth stage, the mixture was pressed into a baking pan lined with baking paper, compacted, and baked in an oven at 150°C for 30 minutes. Finally, the snack bars were removed from the oven and cooled to room temperature before testing.

Data Analysis

This study employed a Completely Randomized Design (CRD) comprising four treatment levels F0 (no seaweed), F1 (10%), F2 (20%), and F3 (30%) based on the research of Kusumaningrum & Rahayu (2018). Testing focused on several aspects: iodine content, moisture content, texture analysis, and hedonic organoleptic assessment. The hedonic organoleptic test involved 25 semi-trained panelists and followed the SNI 01-2346-2015 standard, evaluating parameters such as color, aroma, taste, and texture. Data regarding chemical and textural parameters were analyzed using ANOVA and Duncan's test at a 95% confidence level. Meanwhile, organoleptic data were analyzed using the non-parametric Kruskal-Wallis test, followed by Dunn's test to identify significant differences. All data were processed using SPSS software version 26.

RESULTS

Table 1. Physicochemical Test Results of Snack Bars

Snack Bar Formula	Iodine content	Violence	Water content
F0	12.10±1.02	4027.82±0.04	18.81±0.01
F1	31.33±1.06 ^a	4486.68±0.00 ^a	17.25±0.01 ^a
F2	46.33±1.01 ^b	4333.73±0.05 ^a	16.39±0.02 ^a
F3	60.93±1.49 ^c	4588.65±0.01 ^a	12.53±0.00 ^b

(Note: Values marked with different lowercase letters indicate significant differences ($p < 0.05$), whereas those marked with the same lowercase letters indicate no significant difference ($p > 0.05$)).

Table 2. Hedonic Organoleptic Test Scores for Snack Bars

Snack Bar Formula	Color	Aroma	Flavor	Texture
F0	6.84±0.99 ^a	6.96±1.06 ^a	6.44±1.42 ^a	7.16±0.85 ^b
F1	6.16±1.57 ^a	6.04±1.51 ^b	5.6±1.47 ^{ab}	6.2±1.19 ^b
F2	4.47±1.93 ^b	4.64±1.60 ^c	4.68±1.63 ^b	4.2±1.35 ^c
F3	4.2±1.78 ^b	4.4±1.83 ^c	4.48±1.98 ^b	3.44±1.26 ^c

(Note: Values marked with different lowercase letters indicate significant differences ($p < 0.05$), whereas those marked with the same lowercase letters indicate no significant difference ($p > 0.05$)).

DISCUSSION

Analysis of variance results indicate that the fortification of *K. alvarezii* seaweed flour had a significant effect ($p < 0.05$) on the iodine content of the snack bars. The higher the concentration of added seaweed flour, the greater the increase in iodine content. Preliminary testing of the seaweed flour yielded an iodine value of approximately 136.79 µg/g. These findings align with Mongi *et al.* (2019), who reported iodine contents of 15.28 µg/g for fresh seaweed and 12.32 µg/g for dried seaweed. Formula F1 (10% seaweed flour concentration), which achieved the highest organoleptic scores, contained approximately 31.33 µg/g of iodine. Conversely, the treatment without seaweed flour (F0) showed a relatively low iodine content of 12.82 µg/g; this is presumed to originate from ingredients such as oats and almonds, which contain small amounts of minerals, including iodine. According to the National Institutes of Health (2024), foods relatively low in iodine include non-iodized salt (including many sea salts), fruits and fruit juices, vegetables, plant-based milk alternatives (soy and almond beverages), poultry, pork, beef (excluding liver), and bread made without iodate dough conditioners. The high iodine content in Formula F1 means that a single 25 g serving contributes 783.25 µg of iodine. This amount far exceeds the Recommended Dietary Allowance (RDA) of 150 µg/day established by the Indonesian Ministry of Health (2019); consequently, consumers would need to eat only about 4.47 g (one-fifth of a bar) daily to meet their iodine target, excluding intake from other sources such as table salt and side dishes (Muawanah & Hasanah, 2018). In contrast to the chemical parameters, the fortification of seaweed flour did not have a significant effect ($p > 0.05$) on product hardness as measured by a texture analyzer, although hardness values tended to increase with higher concentrations. Physically, however, the product felt more brittle and prone to crumbling. This is likely due to less homogeneous dough mixing at high concentrations, preventing the seaweed hydrocolloids from binding water optimally and disrupting the formation of a cohesive matrix. Pratyarsi *et al.* (2023) explain that the high fiber content in seaweed dilutes the gluten, thereby disrupting the viscoelastic network that binds the dough and causing the product to lose elasticity and cohesiveness.

The addition of seaweed flour had a significant effect ($p < 0.05$) on the snack bar's moisture content, which decreased as the proportion of seaweed flour increased. This reduction is attributed to the hydrocolloids in *K. alvarezii*, which bind water; consequently, during baking, water mobility is restricted, and a significant portion is released as steam (Utari, 2016).

Lukito *et al.* (2017) further note that the fiber in seaweed flour contributes to this reduction in moisture content. Nevertheless, none of the resulting formulations met the SNI 01-4216-1996 standard, which mandates a maximum moisture content of 11.26%; therefore, further modifications are required to lower the moisture content to meet quality standards.

Visually, increasing the concentration of seaweed flour shifted the color gradation from a deep, dark brown (F0) to a yellowish-light brown (F3), with panelist preference scores declining alongside this color change. This shift occurred because the Maillard reaction and caramelization of the constituent sugars (palm sugar, honey, raisins) were suboptimal due to non-homogeneous mixing at high seaweed concentrations (Baihaggi *et al.*, 2022). Panelists preferred the colors of F0 and F1, as they retained the characteristic brown hue of snack bars. These findings align with Utari (2016), who stated that higher seaweed flour concentrations result in lower organoleptic scores for color.

Seaweed fortification had a significant effect ($p < 0.05$) on aroma acceptance. Treatments F0 and F1 yielded the characteristic sweet aroma of oats, honey, and palm sugar, which panelists found appealing; conversely, F2 and F3 began to exhibit a fishy seaweed odor, albeit still mingled with sweet notes. This fishy aroma stems from the seaweed's natural volatile compounds (Li *et al.*, 2023) and persists despite a 24-hour soaking process (Anggraini, 2018). This is consistent with Djamaludin *et al.* (2024), who noted that increased seaweed flour fortification reduces panelist preference for the product's aroma due to the poor reception of the seaweed's characteristic scent.

Although statistical analysis indicated a significant effect ($p < 0.05$), the organoleptic decline in taste preference across treatments was not drastic, as seaweed flour tends to have a neutral, non-dominant flavor profile. The sweetness from the palm sugar, honey, and raisins remained the dominant flavor, allowing panelists to accept the snack bar even at a 30% concentration. This aligns with Fitri (2023), who stated that seaweed flour has a neutral taste, and is supported by Purwasih *et al.* (2021), who noted that the addition of seaweed does not alter the product's primary flavor profile due to its inherently neutral taste. Regarding texture, there was a significant decrease in consumer preference as the seaweed concentration increased ($p < 0.05$). Formulation F0, which utilized wheat flour, exhibited a dense, cohesive, and elastic texture; the balanced composition resulting from the use of wheat flour yielded a high-quality texture. According to Assiddiq (2024), wheat flour provides superior leavening properties, resulting in a more cohesive snack bar with a texture that is more appealing from a sensory perspective. Conversely, formulations F2 and F3 resulted in textures that were brittle and prone to crumbling; this was due to the reduced gluten content available to bind the dough, leading to suboptimal bonding between ingredients. These findings are corroborated by Sipahutar *et al.* (2021) and Lestari (2019), who reported that the addition of seaweed to food products results in a texture that lacks density and cohesion and is prone to breakage.

CONCLUSION

Based on the research results, it can be concluded that fortifying the snack bar formula with seaweed flour effectively increased iodine content, ranging from 31.33 $\mu\text{g/g}$ to 60.93 $\mu\text{g/g}$. For the snack bar fortified with 10% seaweed flour, a serving of just 4.47 g (one-fifth of a package) is sufficient to meet intake needs. Furthermore, seaweed flour fortification influenced the snack bar's texture and moisture content; hardness values ranged from 4333.74 gf to 4588.65 gf remaining within the commercial limit of 5466.53 gf while moisture content ranged from 12.53% to 17.53%. According to SNI 01-4216-1996, the maximum moisture content for snack bars is 11.26%; consequently, none of the treatments met the quality standard for moisture content. Organoleptic test results indicated that seaweed flour fortification affected the snack bar formula. The treatment with 10% seaweed flour fortification was the formulation most accepted by panelists, as it achieved the highest preference scores for color,

aroma, taste, and texture compared to the 20% and 30% fortification treatments.

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