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The Effect of Carrageenan and Glycerol Addition on the Physicochemical Characteristics of Nori, an Analogue of Genjer Leaves (*Limnocharis flava*)

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A B S T R A C T

tAnalogue nori is produced through cooking, molding, and drying processes using non-seaweed materials. This study utilized genjer leaves (Limnocharis flava) as the primary raw material due to their physical resemblance to commercial nori, with carrageenan added as a gelling agent to improve structural compactness and glycerol as a plasticizer to enhance moisture retention and flexibility. The objective was to determine the optimal carrageenan–glycerol proportion to obtain the best physicochemical qualities. A two-factor Completely Randomised Design with two replications was applied, consisting of carrageenan (1%, 1.5%, and 3%) and glycerol (1%, 1.5%, and 2%) concentrations. The optimal treatment (3% carrageenan and 2% glycerol) produced analogue nori with 14.44% moisture, 12.03% ash, 17.22% fat, 5.31% crude fiber, 5.74% dietary fiber, 40.57% antioxidant activity, 0.45 mg/kg lead, and a tensile strength of 0.0148 N/mm², indicating its potential as a functional nori alternative.

Contribution to Sustainable Development Goals (SDGs):
SDG 2: Zero Hunger
SDG 3: Good Health and Well-Being
SDG 12 : Responsible Consumption and Production
SDG 14 : Life Below Water

1. INTRODUCTION

1.1. Background

Nori, a seaweed-based food product, has seen significant growth in Indonesia, with total imports reaching 321 tons in 2020 [1]. This product is generally made from Porphyra red seaweed, which is crushed, seasoned, and dried to produce thin sheets [2]. However, because Porphyra algae grows optimally in subtropical climates and is very limited in Indonesian waters, the domestic industry remains heavily dependent on imports from countries such as South Korea and Japan [3]. Therefore, innovation in creating analogue nori using local commodities is necessary to reduce this import dependency [4]. One promising local raw material is genjer leaves (Limnocharis flava), an aquatic plant that is abundant and easy to cultivate. The use of green leafy plants, such as genjer, in analogue nori production is supported by their chlorophyll content, which produces a natural green colour resembling commercial nori [4]. Nutritionally, genjer offers high functional value, with very strong antioxidant activity (IC50 of 122 ppm) [5] and a crude fibre content of 18.13% [6]. Utilising genjer is also expected to increase the economic value of a plant that has traditionally been consumed only as a simple side dish.

Using carrageenan alone often results in brittle, rigid sheets; thus, a plasticiser, such as glycerol, is required [2]. Glycerol enhances flexibility and suppleness by reducing intermolecular interactions within the carrageenan polymer chain [7]. As a hygroscopic compound, glycerol effectively absorbs and retains moisture in the final product, helping prevent cracking [8]. The synergy between the structural formation of carrageenan and the elasticity provided by glycerol serves as the basis for producing genjer analogue nori with optimal physicochemical quality.

1.2. Literature Review

1.2.1. Nori and Nori Analogues

Nori is a dried seaweed product typically made from Porphyra species, widely consumed in Indonesia as a snack or sushi wrapper [1] [2]. However, the cultivation of Porphyra is limited to subtropical climates, forcing Indonesia to rely heavily on imports, which reached 321 tons in 2020 [1]. To address this dependency and utilize local resources, researchers are developing "nori analogues"—functional food products that mimic the characteristics of commercial nori using abundant local green vegetables like cassava, Moringa oleifera, and Binahong leaves [6].

1.2.2. Potential of Genjer (Limnocharis flava)

Genjer (Limnocharis flava) is a promising raw material for these analogues, as it is widely available in Indonesian swamps and paddy fields, where it is currently underutilised [4]. Nutritionally, Genjer is a potent functional ingredient, with high crude fibre content (approximately 18.13%) and strong antioxidant activity (IC50 of 122 ppm) [4, 6]. Despite these nutritional benefits, Genjer leaves lack the natural gelling properties of seaweed, resulting in a texture that is not naturally compact or sheet-like, necessitating the use of hydrocolloids and plasticizers to achieve the desired physical properties [9].

1.2.3. The role of carrageenan and glycerol

To replicate the texture of commercial nori, Carrageenan—specifically Kappa-carrageenan extracted from Kappaphycus alvarezii—is utilized as a gelling agent [10, 11]. It functions as a stabilizer and thickener, creating a compact matrix that provides the necessary structural integrity and tensile strength that plant leaves cannot provide on their own [12, 13]. However, due to its hydrophilic sulfate groups, higher carrageenan concentrations can increase the final product's moisture content [6].

In conjunction with carrageenan, Glycerol is employed as a plasticizer to improve the flexibility and elasticity of the nori analogue sheets. As a polyol, glycerol reduces strong intermolecular hydrogen bonding within the polymer matrix, preventing the product from becoming brittle or stiff [11]. While it significantly enhances the "mouthfeel" and prevents breakage, glycerol is also hygroscopic; therefore, excessive addition can lead to increased moisture retention in the nori sheet [7].

1.3. Objective

The primary objective of this study was to investigate the effect of carrageenan and glycerol addition on the physicochemical and organoleptic characteristics of Genjer (Limnocharis flava) leaf nori analogue. Furthermore, this research aimed to determine the optimal combination of these additives to produce a nori analogue with the best quality attributes

2. MATERIALS AND METHODS

2.1. Materials

.The research was conducted between June 2025 and February 2026 at the laboratories of UPN "Veteran" Jawa Timur, utilising cultivated Genjer leaves (Limnocharis flava) from Keputran Market, Surabaya, as the primary raw material, alongside Kappa-carrageenan and glycerol as treatment variables. Employing a Completely Randomized Design (CRD) with a two-factor factorial arrangement— Carrageenan (1%, 1.5%, 3%) and Glycerol (1%, 1.5%, 2%)—the nori analogue was prepared by blanching and blending the leaves into a smooth pulp, mixing them with specific seasonings (shrimp shell extract, garlic, shallot, etc.) and the treatment agents, and drying the homogenized mixture in 28 cm² trays at 50°C for 6.5 hours [2, 3]. The resulting products were subjected to comprehensive analysis, including physicochemical properties (moisture, ash, crude fibre, fat, tensile strength, and colour), functional assays (antioxidant activity via DPPH and dietary fibre). Obtained data were analyzed using ANOVA followed by Duncan's Multiple Range Test (DMRT) at a 5% significance level.

3. RESULT AND DISCUSSION

3.1. Physicochemical Characteristics

The effects of carrageenan and glycerol addition on the physicochemical properties of a genjer-based analogue nori were evaluated in this study. Two-way ANOVA indicated that both additives significantly influenced some chemical and physical parameters, including moisture, ash, and crude fiber contents, as well as color and tensile strength ($p \leq 0.05$). Table 1.

3.1.1. Moisture Content

The analysis of variance (ANOVA) revealed a significant interaction ($p \leq 0.05$) between carrageenan and glycerol concentrations regarding the moisture content of the nori analogue. The values ranged from 7.05% to 14.44%, with the highest moisture content observed in the treatment with 3% carrageenan and 2% glycerol (A3B3)

This increase is attributed to the hydrophilic nature of both additives. Carrageenan contains sulfate groups that bind water strongly, while glycerol has three hydroxyl groups (-OH) that are highly hygroscopic. Consequently, higher concentrations of these components enhance the nori matrix's water-holding capacity, preventing water evaporation during drying. This aligns with findings that higher carrageenan concentrations increase the structural binding of water molecules [13].

3.1.2. Ash Content

Statistical analysis showed that carrageenan concentration had a significant effect ($p<0.05$) on ash content, while glycerol did not. No significant interaction was found between the two factors. The ash content ranged from 13.45% to 16.61%, with the highest value observed at the lowest carrageenan concentration (1%).

The mineral composition of the raw materials contributes to the product's high ash content. The Genjer leaves used had an ash content of 15.45% [6], and the kappa-carrageenan used contained 50.76% ash due to its natural mineral content (calcium, potassium, sodium) [8]. The variation in ash content across treatments reflects the mineral contribution from these ingredients within the matrix.

3.1.3. Crude Fiber Content

Crude fibre values ranged from 3.63% to 4.74%, peaking at the highest carrageenan concentration (3%). The increase in fibre content is attributed to the polysaccharide nature of carrageenan, which contributes to the total fibre load. Glycerol acts as a plasticizer that improves the compactness of the matrix, potentially influencing the retention of fibrous material during processing [14, 15]

Table 1. The mean values of moisture, ash, and crude fiber contents of the analogue nori

Treatment		Moisture (%)	Ash (%)	Crude Fiber (%)
Carrageenan(%)	Glycerol(%)			
1	1	7.05^{c}	17.01^{a}	3.49^{a}
1	1.5	8.37^{c}	16.80^{a}	3.49^{a}
1	2	10.42^{b}	16.03^{a}	3.91^{a}
1.5	1	7.10^{c}	15.81^{a}	3.99^{a}
1.5	1.5	12.45^{a}	15.83^{a}	3.99^{a}
1.5	2	14.28^{a}	15.28^{a}	4.18^{a}
3	1	7.69^{c}	15.07^{a}	4.34^{a}
3	1.5	11.55^{b}	13.24^{a}	4.57^{a}
3	2	14.44^{a}	12.03^{a}	5.31^{a}

Note: Mean values followed by different letters indicate significant differences ($p \leq 0.05$).

Table 2. The Mean value of tensile strength and colors L*a*b*

Treatment		Tensile strength (N/mm^2)	L*	a*	b*
Carrageenan(%)	Glycerol(%)				
1	1	0.0104^{a}	29.30^{a}	-1.68^{a}	3.47^{e}
1	1.5	0.0097^{a}	29.85^{a}	-0.15^{a}	4.57^{e}
1	2	0.0159^{a}	28.29^{a}	0.20^{a}	5.39^{e}
1.5	1	0.0114^{a}	25.66^{a}	0.51^{a}	7.58^{e}
1.5	1.5	0.0123^{a}	30.75^{a}	0.77^{a}	8.79^{d}
1.5	2	0.0120^{a}	28.34^{a}	0.90^{a}	9.19^{c}
3	1	0.0134^{a}	33.99^{a}	1.30^{a}	10.44^{c}
3	1.5	0.0134^{a}	31.98^{a}	2.05^{a}	14.77^{b}
3	2	0.0148^{a}	29.14^{a}	2.88^{a}	18.23^{a}

3.1.4. Tensile Strength

The tensile strength values ranged from 0.0120 to 0.0139 N/mm^2 Tabel 2. Higher carrageenan concentrations resulted in increased tensile strength. This is due to carrageenan's ability to form a rigid, three-dimensional gel matrix, which enhances the structural integrity of the nori sheet and requires more force to break. Glycerol addition did not show a statistically significant effect on tensile strength in this specific range, although it is typically known to increase elasticity [16,17].

*3.1.5. Color (L*a*b*)*

The Lightness (L*) values ranged from 25.66 to 33.99, showing an upward trend with increasing additive concentrations. The highest lightness (31.71) was achieved at 3% carrageenan. This increase is attributed to the formation of a smoother, more compact hydrocolloid matrix at higher concentrations, which reflects light more effectively than the rougher surface textures found in treatments with lower additive levels [18]. An increase in the redness (a*) value was observed with increasing carrageenan concentration, shifting the color profile from greenish (−1.68) at 1% to reddish (2.88) at 3%. This chromatic change is attributed to the dominant pigment in κ-carrageenan, phycoerythrin derived from red seaweed, which progressively masks the natural green chlorophyll pigment of Genjer leaves as the concentration increases [4],[18],[19].

Significant interaction ($p \leq 0.05$) between carrageenan and glycerol was observed for the yellowness (b*) parameter. The values increased drastically, peaking at 18.23 in the formulation with 3% carrageenan and 2% glycerol. This strong yellowing effect is primarily caused by the natural yellowish-white color of the semi- refined kappa-carrageenan powder (18.88) and potential non- enzymatic browning or carotenoid degradation induced by thermal processing during drying [19], [20].

3.1.6. Analysis of Best Treatment

Based on the De Garmo effectiveness index, the formulation with 3% Carrageenan and 2% Glycerol*was determined as the best treatment. Further chemical analysis of this specific formulation yielded the following results:

Table 3. Analysis of Best Treatment

Parameters	Result
Dietary viber	5,74%
Antioxidant activity	40,57ppm
Fat	17,22%
Lead (Pb)	0,450mg/kg

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The Genjer leaf analogue nori demonstrated promising functional properties, containing 5.74% total dietary fiber, which was lower than the 7.59% found in kolesom leaf nori analogue [21] but higher than that of raw Genjer leaves (3.26%), indicating the contribution of carrageenan as a soluble fiber source. The product also exhibited strong antioxidant activity (40.57%), exceeding the values of 14.84–33.02% in Ulva lactuca–Moringa nori analogues [22], likely due to the naturally high phytochemical content of Genjer leaves and the protective effect of the carrageenan matrix during processing. The fat content reached 17.22%, higher than fern-based nori (0.65%) and Ptilophora pinnatifida nori (12.57%) [15, 23], mainly attributed to the addition of sesame oil during seasoning rather than carrageenan or glycerol. However, the detected lead (Pb) level of 0.450 mg/kg exceeded the maximum limit set by SNI 9105:2022, likely due to the phytoremediation capacity of Genjer plants and possible metal residues from seaweed-derived carrageenan, indicating the need for stricter control of raw materials and decontamination to ensure food safety.

4. CONCLUSION

Carrageenan and glycerol influenced the physicochemical characteristics of Genjer leaf analogue nori in different ways. Higher carrageenan levels improved tensile strength and crude fiber content, reduced ash levels, and shifted the color toward a more reddish appearance, while glycerol enhanced moisture retention and lightness. The best formulation, containing 3% carrageenan and 2% glycerol, produced analogue nori with 14.44% moisture, 12.03% ash, 5.31% crude fiber, a tensile strength of 0.0148 N/mm², and color values of L* 29.14, a* 2.87, and b* 18.23. The product also showed functional potential with 5.74% dietary fiber, antioxidant activity (IC50 = 40.57 ppm), and fat 17,22% however, the detected lead content of 0.450 mg/kg exceeded the safety limit, indicating the need for improved raw material control or decontamination to ensure product safety.

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