



Physicochemical Characteristics of Artificial Nori Made from Water Clover (*Marsilea crenata*) Leaves with Different Concentrations of Carrageenan

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ABSTRACT

Indonesia relies heavily on importing commercial seaweed nori, reaching 321 tons annually. To reduce import dependency and utilize local botanical resources, water clover (*Marsilea crenata*), an endemic bioactive-rich fern from East Java, represents a promising alternative raw material. This study aimed to characterize the physicochemical and mechanical properties of artificial nori made from water clover leaves with varying carrageenan concentrations (1%, 1.5%, and 2%). The resulting sheets were analyzed for yield, moisture, ash, protein, crude fiber, total phenolic content, antioxidant activity, tensile strength, and thickness. Results indicated that higher carrageenan concentrations increased yield, moisture, ash, crude fiber, thickness, and tensile strength due to the internal bonds between carrageenan. Conversely, total phenolic content and antioxidant activity decreased because bioactive compounds were less extractable due to entrapment within the matrix. This research requires further optimization to match the mechanical tensile strength of commercial seaweed-based nori.

Contribution to Sustainable Development Goals (SDGs):

SDG 2: Zero Hunger

SDG 9: Industry, Innovation, and Infrastructure

SDG 12: Responsible Consumption and Production

1. INTRODUCTION

1.1. Research Background

Nori is a traditional food originally from Japan that is presented in the form of thin, dried seaweed sheets. It is widely utilized as a culinary condiment in ramen, sushi, and rice balls (onigiri). Furthermore, nori is popular as a snack, typically processed through drying and roasting before being seasoned with diverse flavoring [1]. The red algae, *Porphyra* serves as the primary raw material for nori production. *Porphyra* widely distributed in the waters of East Asia, with limited occurrence in Southeast Asia. Globally, more than 15 *Porphyra* species are present in China [2].

According to data from International Trade Center, Indonesia imported 321 tons of human consumption's seaweed (HS 121221) from several countries, predominantly China, South Korea, and Japan [3]. Therefore, the substitution of *Porphyra* needs to be

studied to reduce the number of imported nori products. One of the potential botanical resources that can be further utilized is the water clover leaves (*Marsilea crenata*).

Water clover is an aquatic fern species. It has long been consumed as traditional food in Indonesia, mainly in Surabaya, East Java [4]. Water clover is an endemic species native to Indonesia [5]. Its utilization as a traditional food in Surabaya, East Java, is limited to *pecel semanggi* (a traditional steamed water clover salad with peanut sauce). A major issue encountered by locals is the underutilization of local potential and limited marketing for processed products. Consequently, developing water clover through innovation represents a viable strategy to enhance the potential of water clover itself. [6].

Traditional food resources, such as water clover, are recognized for their beneficial properties. Several phytochemical screening of water clover has qualitatively identified compounds such as flavonoids, steroids, alkaloids, neophyadiene, phytol,



palmitic acid, and elaidic acid [4], [7]. These compounds exhibit antioxidant activity and functions. Antioxidants inhibit oxidative process through free radical scavenging mechanisms. Dietary antioxidant supplementation obtained from food intake can inhibit excessive free radicals in the body [8].

Addition of binding agents are required in the production of artificial nori due to its function to improve physical and sensory quality profiles. Carrageenan is one of binding agent that is widely used in nori processing. Derived from red seaweed *Eucheuma cottonii*, carrageenan is predominantly used for its functional capacity as a binder rather than its nutritional content [9]. This functional attribute relates to its gel-strength capability [10]. The gelation process relies on the hydrocolloid behavior, which binds water and allows the matrix to form cohesive sheets [11].

Physicochemical studies regarding alternatives materials other than seaweeds for artificial nori making have been conducted before, such as artificial nori from grass jelly leaves with addition of carrageenan [11]. However, the effects of carrageenan concentration on the physicochemical and mechanical properties of artificial nori made from water clover leaves have not been investigated.

This study is necessary to drive an added value innovation for water clover leaves, thereby improving the economic potential of the raw materials. The superior nutritional and phytochemical profiles of this ingredient offer distinct advantages over commercial nori. Additionally, the development of artificial nori expected to reduce the dependence on seaweed nori imports or commercial nori products in Indonesia.

1.2 Literature Review

Nori possesses a distinctive flavor favored by consumers and is rich in nutrients, including protein, lipids, minerals, dietary fiber, and vitamins. The presence of amino acids, particularly glutamate, glycine, and alanine, plays a crucial role in contributing to the unique flavor profile of nori [12]. Nori exhibits a dry, smooth texture with a lustrous dark green appearance, attributed to the pigment content from its raw material, *Porphyra* seaweed, which can constitute up to approximately 40% of dried nori [13].

Commercial nori is relatively nutrient-dense, with protein ranging from 25% to 50% on a dry weight basis, lipid content of 2% to 3% on a dry weight basis, and various vitamins. Nori contains several amino acids that favorably contribute to its flavor profile, such as glutamic acid, glycine, and alanine. Additionally, dietary fiber represents a major constituent in seaweed, with nori containing up to 34% dietary fiber on a dry weight basis [14].

Alternative formulations of nori utilizing non-algae plant sources have been extensively researched, including grass jelly (*Cyclea barbata*), water spinach (*Ipomoea aquatica*), and moringa (*Moringa oleifera*) leaves [11], [14], [15]. The use of substitute raw materials can lead to variations compared to commercial nori, affecting characteristics such as appearance, color, texture, and nutritional content. Additional ingredients with binding properties or gelling agents can be incorporated into artificial nori formulations to improve physical properties, particularly texture, to closely resemble commercial nori [16].

Marsilea crenata represents a distinct botanical species indigenous to East Java, Indonesia. they are incorporated into a traditional dish known as *pecel*. The utilization of water clover extends beyond food applications, as its leaves and stems are also

used as a natural diuretic to promote urination [7]. water clover is rich in essential micronutrients, including calcium, iron, magnesium, vitamin A, and vitamin C [17].

An ethanol extract of water clover administered at a dose of 200 mg/kg BW in carrageenan-induced (inflammatory) mice exhibited an anti-inflammatory activity of 70.15%, compared to only 61.14% in the control group. This anti-inflammatory effect is presumed to originate from secondary metabolites present in the water clover extract, namely flavonoids, alkaloids, and steroids. Flavonoids exert their anti-inflammatory effect by inhibiting arachidonic acid pathways as well as lysosomal and endothelial enzyme secretions [8].

The primary challenge limiting the popularity of water clover as a processed product is the underutilized potential by local farmers coupled with a lack of synergy with governmental institutions [6]. Given the anti-inflammatory activity of water clover demonstrated in previous research, its potential for further development into value-added processed products warrants detailed exploration.

Carrageenan is the commercial name for a group of sulfated galactans extracted from red seaweeds. The polysaccharide composition of red seaweeds differs substantially from that of land plants, as sulfated galactans constitute the primary structural component of their cell walls and intercellular matrix. Carrageenan possesses gel-forming ability and functions as a stabilizer. It is categorized as a food additive commonly utilized as a texture modifier. Among the commercially produced carrageenans, kappa- and iota-carrageenan act as gelling agents, whereas lambda-carrageenan does not form gels [18]. Kappa-carrageenan is frequently utilized in food product applications [14].

Carrageenan gelation begins through the alignment and interaction of single random coils to form double helices. The accumulation of these double-helical domains subsequently constructs a cross linked three dimensional polymer network. Characterized by thermoreversibility, the resulting gel undergoes liquefaction when subjected to elevated temperatures and recovers its structural integrity upon cooling, with no diminution of gel strength [18].

1.3 Research Objective

This study aimed to characterized physicochemical properties of artificial nori made from water clover leaves (*Marsilea crenata*) with the addition of various levels of carrageenan (1%; 1,5%; 2%).

2. MATERIALS AND METHODS

This research was conducted from August 2025 to April 2026 at the Laboratory of Food Technology, Faculty of Engineering and Science, UPN "Veteran" Jawa Timur, Indonesia and the Laboratory of Food Technology and Agriculture, Universitas Gadjah Mada. The raw material used was water clover leaves (*Marsilea crenata*) obtained from local farmers at Benowo, Surabaya, Indonesia. Kappa-carrageenan used as binding agent for the artificial nori.

Artificial Nori making begins with sortation of water clover leaves and weighed 50 grams. The water clover leaves then blanched at 70°C for 2 minutes. The blanched leaves were mixed with water at 1:1 ratio and homogenized with a blender to form a puree. The puree then mixed with carrageenan at varying

concentration (1%;1,5%; and 2% of 50gram water clover leaves). The mixture then poured and spread onto a 25×30cm baking tray then dried with an oven at 70°C for 4 hours. The dried product was then collected as artificial nori.

3. RESULT AND DISCUSSION

The artificial nori was characterised by certain parameters, such as yield, moisture content, ash content, protein, crude fibre content, total phenolic content, antioxidant activity, tensile strength, and thickness.

3.1. Yield

Yield analysis aims to determine the percentage ratio of the final artificial nori product weight to the initial raw material weight, reflecting the efficiency of the production process in terms of both economic and productivity value.

Table 1. Yield, tensile strength, and thickness of water clover artificial nori

Carrageenan levels	Yield (%)	Tensile Strength (MPa)	Thickness (mm)
1.0%	6.31±0.0	0.88±0.2	0.30±0.1
1.5%	6.99±0.1	2.49±0.2	0.33±0.0
2.0%	7.20±0.2	4.30±0.7	0.34±0.0

The drying process utilizes thermal energy, which induces moisture loss from the material as drying progresses [19]. Plant fibers possess hydrophilic characteristics [20], and serve as major structural components that contribute to overall plant biomass [21]. Furthermore, carrageenan is a hygroscopic polymer with gelation capacity during heat treatment; it will effectively entraps water molecules within the raw material matrix during dehydration, increasing the overall product yield [22].

3.2. Tensile Strength

Evaluating tensile strength represents an essential physical characterisation for nori to quantify the sheet's resilience against applied mechanical stress. Tensile strength was tested using a Universal Testing Machine (UTM).

The increasing trend, as shown in **Table 1**, is presumably attributed to the capacity of carrageenan to reinforce the nori matrix, where higher carrageenan concentrations directly enhance the tensile strength of artificial nori. Nori's tensile strength is governed by the raw material formulation, whereas a stronger gel network leads to a higher tensile strength value [23]. Furthermore, intrinsic fiber networks provide structural reinforcement, with higher fiber levels in raw materials resulting in a firmer and stronger product texture [24].

Carrageenan gelation occurs through the cross-linking of polymer chains to establish a continuous three-dimensional network. This network entraps water within its structure, thereby producing a strong and rigid framework [14]. Overall, the tensile strength of the water clover artificial nori in this study remains considerably lower than that of commercial nori, which stands at 64.04 MPa [25].

3.3. Thickness

Evaluating the physical attribute of thickness is essential for characterizing sheet-form products, serving as a primary dimensional index for nori. Table 1 shows the thickness of water clover leaf artificial nori.

Thickness values of artificial nori can be attributed to the volume of the mixture cast onto the tray [25]. Higher concentrations of carrageenan used in edible film formulation positively correlate with an increase in total solids within the mixture, resulting in a thicker film upon drying [26]. The average thickness of the produced artificial nori exceeds the standard range for vegetable leather or edible films, approximately 0,25mm [27].

3.4. Moisture Content

Moisture content analysis is essential as water content plays a crucial role in determining the physical stability and overall quality of food products.

Table 2. Moisture, ash, protein, and crude fiber of water clover artificial nori

Carrageenan levels	Moisture (%)	Ash (%)	Protein (%)	Crude Fiber (%)
1.0%	12.54±0.8	6.36±0.4	28.41±0.3	12.22±0.2
1.5%	14.92±0.9	8.60±0.9	29.57±0.0	12.43±0.0
2.0%	15.06±1.0	8.66±0.9	29.61±0.0	12.68±0.3

The macronutrient composition of the leaf raw materials can influence the final product's moisture content. The fiber content in the product significantly affects its water absorption capacity [28]. Artificial nori exhibited a high moisture content, owing to its high crude fiber content. Moisture content positively correlates with product yield: higher moisture content corresponds to higher yield.

Carrageenan plays a significant role in increasing the moisture content in artificial nori production. A hydrogel consists of a polymer network capable of entrapping water without being dissolved [23]. As a hydrogel-forming agent, carrageenan binds and entraps water within its matrix to facilitate gelation [29]. According to the latest research of nori-like product derived from grass jelly leaves, the addition of carrageenan to the nori-like product resulted in a progressively higher average moisture content with increasing concentrations of carrageenan incorporated into the mixture [11].

3.5. Ash Content

The analysis of ash content parameter is conducted to determine the total mineral content present in a product. Table 2 shows the ash content of artificial nori.

The resulting ash content is intrinsically dependent upon the mineral composition of the raw materials incorporated into the product [30]. Fresh water clover leaves and petioles contain several minerals, including phosphorus (142.8 mg/100 g), calcium (69.05 mg/100 g), potassium (937.56 mg/100 g), sodium (69.6 mg/100 g), iron (108.3 mg/100 g), copper (5.19 mg/100 g), and zinc (7.56 mg/100 g) [31].

Adding carrageenan increases the ash content percentage of artificial nori. In a previous study, kappa-carrageenan utilized to formulate artificial nori from yellow bur-head (*Limnocharis flava*) leaves yielded an ash content of 50.76% [32]. The ash

content of the artificial nori in this study remains lower than that of commercial nori (9.46%) [33].

3.6. Protein

Protein is an essential macromolecule possessing vital functional properties, that is necessary to be analyzed. Protein content of this research was conducted with kjeldahl method. Protein of water clover leaves artificial nori can be seen in **Table 2**.

This high protein content on artificial nori might be due to the nitrogen metabolism mechanism employed by water clover in response to heavy metal exposure stress, specifically through the synthesis of various metabolites, predominantly specific amino acids [34]. Indirectly, this mechanism leads to an abundance of free amino acids in water clover leaves.

Carrageenan exhibits high reactivity toward proteins. The interaction between carrageenan and proteins can occur via two primary mechanisms, divalent cation bridging and ionic bonding [18]. The gelation process takes place when interactions between the negatively charged groups on the polysaccharide and the positively charged groups on the protein form a soluble complex [35]. Carrageenan contains sulfate groups, which carry a negative charge and can form ionic bonds with arginine residues in proteins [36].

3.7. Crude Fiber

Determination of crude fiber content is conducted to quantify the insoluble dietary fiber fraction that resists acid and alkaline digestion. The crude fiber content of water clover leaves artificial nori can be seen in **Fig. 1**.

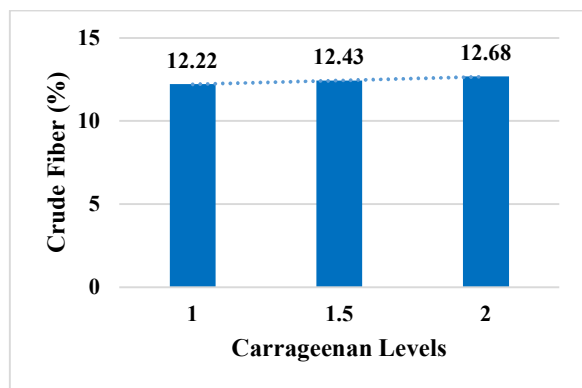


Fig 1. Crude fiber of Artificial Nori

Crude fiber primarily consists of lignin and cellulose, along with minor fractions of hemicellulose and other plant components [37]. Water can be retained within the capillaries formed by insoluble fibers due to surface tension forces or through chemical interactions via hydrogen bonding [38]. Therefore, the crude fiber content in water clover artificial nori correlates positively with moisture content, as water is entrapped not only by the incorporated carrageenan but also by the substantial crude fiber matrix.

Higher additions of carrageenan resulted in an increased crude fiber content. This observation aligns with previous research on green grass jelly gels supplemented with carrageenan, where higher carrageenan concentrations led to an elevation in crude fiber levels [10], which is presumably attributed to the soluble fiber fractions present in carrageenan [15].

3.8. Total Phenolic Content

Analysis of total phenolic content is crucial because phenolic compounds contribute significantly to antioxidant activity. Total phenolic content of this research was conducted with folin-ciocalteau method. The sample extracted with ethanol. The extracted samples then tested with UV-Vis spectrophotometer in 765nm wavelength

Table 3. Total phenolic content and antioxidant activity of artificial nori

Carrageenan	Total Phenolic Content (mg GAE/g)	Antioxidant Activity (%)
1.0%	7.70 ± 0.16	82.01 ± 0.35
1.5%	7.24 ± 0.01	81.81 ± 0.49
2.0%	7.19 ± 0.03	81.61 ± 0.36

Higher carrageenan addition to the solution decreased the total phenolic content of water clover artificial nori. Carrageenan that is served as a hydrocolloid, a gelling agent capable of entrapping water, thereby imparting a rigid and firm structure to the product [14]. This capability increases the amount of free water bound by carrageenan, which consequently reduces the solubility of antioxidant compounds [39]. Furthermore, non-covalent interactions, specifically hydrogen bonding between polyphenol hydroxyl groups (-OH) and polysaccharides can occur [40]. The reduction in measured phenolic content may be related to reduced extractability due to restricted solvent accessibility during extraction.

3.9. Antioxidant Activity

Antioxidant activity analysis is an essential parameter for determining a product's potential to scavenge free radicals. Antioxidant activity of this research was conducted with DPPH method. Samples were extracted with 80% methanol. The extracted samples then tested with UV-Vis spectrophotometer in 517nm wavelength. Table 3 shows a decreasing trend in the antioxidant activity of water clover leaves artificial nori.

Antioxidant activity is influenced by the growth habitat, environmental stress, as well as the morphology and physiological characteristics that affect the stability of plant antioxidant compounds [41]. Water clover leaves contain various antioxidant components, including monoterpenoids, diterpenoids, neophytadiene, palmitic acid, alkaloids, steroids, flavonoids, and amino acids [4], [7]. Water clover also exhibits a high vitamin C content of 66.58 mg/100 g [31]. This high antioxidant activity is further supported by the substantial total phenolic content present in water clover leaves.

The reduction in antioxidant activity can be attributed to the binding of free water by carrageenan, which decreases the solubility of antioxidant compounds and subsequently leads to lower overall antioxidant activity [39].

4. CONCLUSION

Based on the experimental findings, formulating artificial nori from water clover (*Marsilea crenata*) leaves with carrageenan as a hydrocolloid influenced the physicochemical and mechanical attributes of the final product. Increasing carrageenan concentrations enhanced the product yield, moisture content, ash content, crude fiber content, tensile strength, and sheet thickness.

Carrageenan has impact on increasing overall physics and chemical properties of water clover leaves carrageenan due to internal bond between carrageenan itself. Conversely, carrageenan addition led to a reduction in total phenolic content and antioxidant activity due to the sequestering of bioactive compounds within the hydrogel matrix, which restricted their extraction solubility. The limitation of this research was there is no control treatment. Further optimization is required to be able to match with commercial nori.

REFERENCE

- [1] R. R. A. Nurcahyani, S. Aminah, and M. F. Kurniawan, "Karakteristik organoleptik dan kimia snack nori dari daun chaya dan tapioka," *J. Pangan dan Gizi*, vol. 12, no. 1, pp. 60–70, 2022, doi: 10.26714/jpg.12.1.2022.60-70.
- [2] J. Cao, J. Wang, S. Wang, and X. Xu, "Porphyra species: A mini-review of its pharmacological and nutritional properties," *J. Med. Food*, vol. 19, no. 2, pp. 111–119, 2016, doi: 10.1089/jmf.2015.3426.
- [3] E. Sinurat, D. Fransiska, B. S. B. Utomo, Subaryono, Nurayati, and Sihono, "Characteristics of Nori-Like Product Prepared from Seaweeds Growing in Indonesia," *J. Aquat. Food Prod. Technol.*, vol. 31, no. 6, pp. 525–535, 2022, doi: <https://doi.org/10.1080/10498850.2022.2077677>.
- [4] B. Ma'arif, M. Agil, and H. Laswati, "Phytochemical Assessment on n-Butanol ekstrak and fractions of Marsilea crenata Presl. Leaves Through GC-MS," *J. Tradit. Med.*, vol. 21, no. 2, pp. 77–85, 2016.
- [5] Wisanti, D. C. Aloysius, S. Zubaidah, and S. R. Lestari, "Morphological character variation of marsilea crenata L. Living in floating aquatic, emergent aquatic, and terrestrial," *Biodiversitas*, vol. 22, no. 7, pp. 2853–2860, 2021, doi: 10.13057/biodiv/d220736.
- [6] Y. Ermawati, A. Aminatuzuhro, and S. M. Maulana, "Menggali Potensi Lokal melalui Pengembangan UMKM dan Peluang Desa Wisata dalam Pemulihan Covid-19 di Kampung Semanggi, Surabaya," *Fokus ABDIMAS*, vol. 01, no. 01, pp. 18–24, 2022, [Online]. Available: <https://www.ejournal.stiepena.ac.id/index.php/abdimas/article/view/525%0Ahttps://www.ejournal.stiepena.ac.id/index.php/abdimas/article/viewFile/525/357>
- [7] Nurjanah, A. Azka, and A. Abdullah, "Aktivitas Antioksidan Dan Komponen Bioaktif Semanggi Air (Marsilea Crenata)," *J. Inov. dan Kewirausahaan*, vol. 1, no. 3, pp. 152–158, 2012.
- [8] S. Fatimah, E. Suprasetya, and J. Y. Hernawan, "Aktivitas Antiinflamasi Ekstrak Etanol Daun SEManggi Air (Marsilea crenata) pada Mencit Putih (Mus musculus L.) dengan Induksi Karagenin," *J. Permata Indones.*, vol. 15, no. 1, pp. 48–50, 2024.
- [9] E. Desiana and T. Y. Hendrawati, "Pembuatan karagenan dari Eucheuma cottoni dengan ekstraksi KOH menggunakan variabel waktu ekstraksi," in *Seminar Nasional Sains dan Teknologi*, 2015, pp. 1–7.
- [10] W. Atmaka, Af'idatusholikhah, S. Prabawa, and B. Yudhistira, "Pengaruh variasi konsentrasi kappa karagenan terhadap Karakteristik fisik dan kimia gel cincau hijau (Cyclea barbata L. Miers)," *War. Ind. Has. Pertan.*, vol. 38, no. 1, pp. 25–35, 2021, doi: 10.32765/wartaihp.v38i1.6093.
- [11] S. D. Prabaningrum, V. P. Bintoro, and S. B. M. Abduh, "Pengaruh konsentrasi bahan pengikat terhadap nilai rendemen, kadar air, aktivitas air, dan warna pada nori artifisial daun cincau," *J. Apl. Teknol. Pangan*, vol. 11, no. 2, pp. 47–52, 2022, [Online]. Available: <https://doi.org/10.17728/jatp.14367>
- [12] Sihono *et al.*, "Optimization of Nori-Like Product Formulation from Ulva spp., Gracilaria sp., and Glycerol Using Mixture Design Method," *J. Pengolah. Has. Perikan. Indones.*, vol. 26, no. 3, pp. 433–447, 2023, doi: 10.17844/jphpi.v26i3.48337.
- [13] J. Zhang, T. Nagahama, H. Ohwaki, Y. Ishibashi, Y. Fujita, and S. Yamazaki, "Analytical Approach to the Discoloration of Edible Laver 'Nori' in the Ariake Sea," *Anal. Sci.*, vol. 20, no. 1, pp. 37–43, 2004, doi: 10.2116/analsci.20.37.
- [14] S. F. Isnaini, "Karakteristik Nori Dari Daun Kelor Dengan Penambahan Karagenan Dan Pati Garut Sebagai Bahan Pembentuk Gel," Universitas Jember, 2018. [Online]. Available: https://repository.unej.ac.id/xmlui/bitstream/handle/123456789/100892/Syayyidah_Faizatul_Isnaini_141710101069.pdf?sequence=1
- [15] N. Stevani, A. Mustofa, and Y. W. Wulandari, "Pengaruh lama pengeringan dan penambahan karagenan terhadap karakteristik nori daun kangkung (Ipomoea reptans Poir)," *J. Teknol. dan Ind. Pangan*, vol. 3, no. 2, pp. 85–96, 2019.
- [16] E. Sinurat, Nurhayati, D. Fransiska, and Sihono, "Substitution of red seaweed (Porphyra) with other seaweeds in nori making," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 733, no. 1, 2021, doi: 10.1088/1755-1315/733/1/012109.
- [17] M. Agil, I. Kusumawati, and N. Purwitasari, "Phenotypic variation profile of Marsilea crenata Presl. cultivated in water and in the soil," *J. Bot.*, vol. 2017, 2017, doi: 10.1155/2017/7232171.
- [18] C. Popescu, M. Iordan, and B. Cristian, "Structure and properties of carrageenan," *Polym Chem*, pp. 27–32, 2007.
- [19] C. Anwar, I. Irmayanti, and G. Ambartiasari, "Pengaruh Lama Pengeringan terhadap Rendemen, Kadar Air, dan Organoleptik Dendeng Sayat Daging Ayam," *J. Peternak. Sriwij.*, vol. 10, no. 2, pp. 29–38, 2021.
- [20] A. Céline, S. Fréour, F. Jacquemin, and P. Casari, "The hygroscopic behavior of plant fibers : a review," *Front. Chem.*, vol. 1, no. 43, pp. 1–12, 2014, doi: 10.3389/fchem.2013.00043.
- [21] T. G. M. Van De Ven, *Cellulose-Fundamental Aspects*. Intech, 2013.
- [22] S. Sabil, F. Maruddin, T. Wahyuni, and M. Taufik, "Edible film characteristics at different casein concentrations," in *IOP Conference Series: Earth and Environmental Science*, 2021, pp. 1–7. doi: 10.1088/1755-1315/788/1/012115.
- [23] D. F. Rosida, F. Putri Nurani, and M. I. M. Danil Ilmi, "The Nori Gracilaria sp. with a Variation of Stabilizers as Healthy Food," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1125, no. 1, p. 012104, 2021, doi: 10.1088/1757-899x/1125/1/012104.
- [24] J. F. Kurnia, E. N. Dewi, and R. A. Kurniasih, "Pengaruh konsentrasi bubur Eucheuma cottonii terhadap karakteristik selai lembaran," *J. ilmu dan Teknol. Perikan.*, vol. 3, no. 1, pp. 43–49, 2021.
- [25] M. Limonu, Y. Bait, A. Engelen, and N. Muhsin, "Seaweed nori (Kappapycus alvarezii) physicochemical and organoleptic characteristics with moringa leaf fortification (Moringa oleifera LAM)," *Agrointek J. Teknol. Ind. Pertan.*, vol. 18, no. 2, pp. 360–372, 2024, doi: 10.21107/agrointek.v18i2.16764.
- [26] D. Handito, "Pengaruh konsentrasi karagenan terhadap sifat fisik dan mekanik edible film," *Agroteksos*, vol. 21, no. 2, pp. 151–157, 2011.

- [27] S. Wahyuni, Holilah, Asranudin, M. I. K. Rianse, and M. S. Sadimantara, "Effect of κ -carrageenan concentration on physical and Mechanical properties of vegetable leather based on kelor leaves (*Moringa oleifera* L.)," in *IOP Conference Series: Earth and Environmental Science*, 2019, vol. 260. doi: 10.1088/1755-1315/260/1/012180.
- [28] M. S. Siregar, I. Syukri, H. Rusmarilin, and D. Ardilla, "Studi Pembuatan Minuman Serat Alami yang Kaya β -Karoten," *J. Teknol. dan Ind. Pertan. Indones.*, vol. 15, no. 01, pp. 8–15, 2023.
- [29] A. Wulansari, R. Andriani, and E. K. Dewi, "Variasi Bahan Baku dan Metode Pembuatan Nori Tiruan: Kajian Pustaka," vol. 3, no. 1, pp. 1–11, 2020.
- [30] D. Fransiska *et al.*, "Karakteristik Nori Campuran Rumput Laut Ulva sp. dan Gracilaria sp. yang Diproses dengan Metode Casting," *J. Pascapanen dan Bioteknol. Kelaut. dan Perikan.*, vol. 17, no. 2, p. 99, 2022, doi: 10.15578/jpbkp.v17i2.728.
- [31] A. M. Jacob, Nurjanah, M. Arifin, W. Sulistiono, and S. S. Kristiono, "Deskripsi Histologis dan Perubahan Komposisi Kimia Daun dan Tangkai Semanggi Air (*Marsilea crenata*, Presl., *Marsileaceae*) Akibat Perebusan," *Jurnal Pengolahan Hasil Perikanan Indonesia*, vol. 13, no. 2, pp. 81–95, 2010.
- [32] S. A. P. Simangunsong and Rosida, "The Effect of Carrageenan and Glycerol Addition on the Physicochemical Characteristics of Nori, an Analogue of Genjer Leaves (*Limncharis flava*)," *Asian J. Appl. Res. Community Dev. Empower.*, vol. 10, no. 1, pp. 174–178, 2026.
- [33] P. P. Pamungkas, S. S. Yuwono, and K. Fibrianto, "Potensi rumput laut merah (*Gracilaria gigas*) dan penambahan daun kenikir (*Cosmos caudatus*) sebagai bahan baku pembuatan nori," *J. Teknol. Pertan.*, vol. 20, no. 3, pp. 171–180, 2019.
- [34] F. Rachmadiarti and G. Trimulyono, "Phytoremediation capability of water clover (*Marsilea crenata* (L). Presl.) in synthetic Pb solution," *Appl. Ecol. Environ. Res.*, vol. 17, no. 4, pp. 9609–9619, 2019.
- [35] O. N. Makshakova and Y. F. Zuev, "Interaction-Induced Structural Transformations in Polysaccharide and Protein-Polysaccharide Gels as Functional Basis for Novel Soft-Matter : A Case of Carrageenans," *Gels*, vol. 8, no. 287, pp. 1–17, 2022.
- [36] P. S. Chauhan and A. Saxena, "Bacterial carrageenases: an overview of production and biotechnological applications," *3 Biotech*, vol. 6, no. 146, pp. 1–18, 2016, doi: 10.1007/s13205-016-0461-3.
- [37] C. Madhu, B. Sanjay, K. Harshitha, J. Pradham, and S. S. N. Sree, "Review article on crude fiber," *J. Multidiscip. Res.*, vol. 5, no. 3, pp. 30–33, 2025.
- [38] S. Naumann, U. Schweiggert-weisz, A. Martin, M. Schuster, and P. Eisner, "Food Hydrocolloids Effects of extrusion processing on the physicochemical and functional properties of lupin kernel fibre," *Food Hydrocoll.*, vol. 111, pp. 1–11, 2021, doi: 10.1016/j.foodhyd.2020.106222.
- [39] S. N. Anggraeni, "Karakteristik Vegetable Leather Daun Alur (*Suaeda maritima*) dengan Variasi Konsentrasi Pektin dan Sukrosa," Universitas Pembangunan "Veteran" Nasional Jawa Timur, 2025.
- [40] L. Jakobek, "Interactions of polyphenols with carbohydrates , lipids and proteins," *Food Chem.*, vol. 175, pp. 556–567, 2015, doi: 10.1016/j.foodchem.2014.12.013.
- [41] R. R. Kotha, F. S. Tareq, E. Yildiz, and D. L. Luthria, "Oxidative Stress and Antioxidants—A Critical Review on In Vitro Antioxidant Assays," *Antioxidants*, vol. 11, no. 2388, 2022.