IJFSNI 234 57-64

by Go MIT

Submission date: 20-Nov-2026 11:41AM (UTC+0700)
Submission ID: 3094947864
File name: IJFSNI_234_57-64.docx (5.88M)
Word count: 4181
Character count: 26800

International Journal of Food Sciences And Nutrition Innovations
Volume 2, Issue 2, 57-64.
e_ISSN: 3109-9025
https://e-journal.gomit.id/ijfsni
DOI : 10.58723/ijfsni.v2i2.234

Development of Innovative Functional Food from Red Seaweed (*Eucheuma cottonii*): Pudding Formulation and Literature Review of Its Biological Activity

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Article Info

Article history:

Received: August 14, 2026
Revised: October 27, 2026
Accepted: November 02, 2026

Keywords:

Antiaging;
Antioxidant;
Eucheuma cottonii;
Functional food;
Marine.

Abstract

Background: *Eucheuma cottonii* is a red seaweed rich in bioactive compounds, including phenolics, flavonoids, phycoerythrin, β-carotene, and carrageenan, which have been associated with antioxidant and health-promoting activities. However, its utilization remains largely limited to semi-processed products.
Objective: This study aimed to develop *E. cottonii* pudding as an innovative functional food and evaluate its potential as a natural dietary source of antioxidants to reduce oxidative stress and support premature aging prevention.
Methods: The pudding was prepared through eight stages: washing, soaking, re-washing, boiling in coconut water, preparation of a biscuit base, incorporation of seaweed agar, cooling, and topping. Its functional potential was evaluated based on physical characteristics and a literature review of the major bioactive compounds and biological activities of *E. cottonii*.
Result: The pudding exhibited an attractive reddish-purple color associated with phycoerythrin and a firm yet tender texture attributed to carrageenan. Coconut water reduced the characteristic seaweed odor and provided additional nutritional value. Literature findings indicate that *E. cottonii* bioactive compounds possess antioxidant, anti-free-radical, collagenase-inhibitory, photoprotective, antimicrobial, and tissue-regenerative activities.
Conclusion: *E. cottonii* pudding shows potential as an innovative functional food combining acceptable sensory characteristics with the health benefits of red seaweed bioactive compounds. Further quantitative antioxidant, sensory, proximate, stability, and clinical studies are needed to confirm its functional efficacy.

To cite this article: Aly et al,. (2026). Development of Innovative Functional Food from Red Seaweed (Eucheuma cottonii): Pudding Formulation and Literature Review of Its Biological Activity. *Journal of Food Sciences And Nutrition Innovations*, 2(2), 57-64. https://doi.org/10.58723/ijfsni.v2i2.234

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INTRODUCTION

Indonesia is the world's largest archipelagic nation, possessing abundant marine resources with significant potential for development into functional foods. One widely cultivated marine commodity is seaweed specifically the red seaweed (*Eucheuma cottonii*) which is prevalent in Indonesian waters due to its high economic value and suitability for sustainable cultivation (Sutaman et al., 2026). This seaweed is utilized not only as an ingredient in food and non-food industries but also holds great potential as a source of bioactive compounds beneficial to health (Mahardika & Samirana, 2026).

In general, *E. cottonii* contains various secondary metabolites such as flavonoids, phenolics, alkaloids, and triterpenoids as well as carrageenan, all of which possess significant biological activity, particularly as natural antioxidants (Megawati et al., 2024; Nurilmala et al., 2017). These compounds play a role in scavenging free radicals unstable, reactive molecules that can damage cells due to

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unpaired electrons. An imbalance between free radical production and the body's antioxidant capacity can lead to oxidative stress, resulting in cellular and tissue damage (S et al., 2015).

Oxidative stress is known to be a primary factor triggering various degenerative diseases such as cancer, cardiovascular disease, and cataracts and accelerating the process of premature aging (Ames et al., 1993; Nandi et al., 2019). Premature aging itself results from the cumulative damage to collagen and skin cell structures caused by long-term exposure to free radicals. This situation highlights the importance of obtaining antioxidants from external sources to help balance the body's endogenous antioxidant defense system (Chandimali et al., 2025).

In line with this, various studies have demonstrated that *E. cottonii* extract possesses significant biological activity. Its phenolic and flavonoid content exhibits high antioxidant activity (Saadatul Husna et al., 2023; Syafitri et al., 2022), the ability to inhibit collagenase an enzyme involved in collagen degradation associated with skin aging (Fitriyah, 2021) and photoprotective potential as a natural sunscreen agent (Anggraeni et al., 2026). Furthermore, *E. cottonii* has been reported to exhibit antibacterial activity against various pathogens (Astriani & Nurjanah, 2023) and to accelerate wound healing through its antioxidant activity (Teo et al., 2021).

However, the utilization of *E. cottonii* remains dominated by its use as a raw material for semi-processed industrial products such as agar and carrageenan (van der Heijden et al., 2022). Consequently, there is a need for innovation in developing functional food products that are easier to consume and more widely accepted by the public. Functional foods are defined as foods that not only meet basic nutritional needs but also offer additional physiological health benefits(Mohammadi & Ostovar, 2025; Nima & Nikoo, 2025). In this context, the development of seaweed pudding presents an innovative alternative, as it offers an appealing texture, a simple production process, and the versatility to be combined with other complementary ingredients.

The development of *E. cottonii* pudding therefore represents an opportunity to bridge the gap between the established biological potential of red seaweed and its practical utilization as a consumer-oriented functional food. Pudding provides a convenient and attractive food matrix in which the natural gelling properties of carrageenan can be utilized to produce a desirable texture, while incorporating coconut water may help reduce the characteristic seaweed odor and provide additional nutritional components.

Based on the foregoing, this study focuses on the formulation of *E. cottonii* (red seaweed) pudding as a functional food and on an analysis of the product's potential bioactive content specifically, its role as a source of natural antioxidants that combat free radicals and help prevent premature aging.

METHOD

Research Design

This study employed an exploratory product-development design to develop *E. cottonii* red seaweed pudding as a potential functional food. The research consisted of two complementary components; (1) formulation and preparation of the *E. cottonii* pudding and (2) a narrative assessment of its potential functional properties based on previously reported bioactive compounds and biological activities of *E. cottonii*(Kang et al., 2019; Lee, 2006).

The product-development component focused on the processing characteristics and physical attributes of the pudding, including color, texture, aroma, and overall product appearance. The functional potential of the product was subsequently interpreted based on published evidence concerning the antioxidant, anti-radical, collagenase-inhibitory, photoprotective, antimicrobial, and tissue-regenerative properties of *E. cottonii*. This approach was selected because the present study was intended as an initial product-development investigation rather than a clinical intervention or direct evaluation of anti-aging efficacy(Choi et al., 2021; Ciganović et al., 2023).

Instrument

The primary material used in this study was fresh red seaweed (*Eucheuma cottonii*) collected from Jember, East Java, Indonesia in May 2026. Other ingredients used in the pudding formulation included fresh coconut water, palm sugar and/or white sugar, biscuits, butter, and Vla. Clean water and running water were used during the washing and soaking processes.

The equipment used during product preparation consisted of standard food-processing and laboratory equipment, including a washing container, soaking container, cooking vessel, stove or heating apparatus, knife, cutting board, blender or suitable homogenization equipment, measuring equipment, pudding molds or containers, refrigerator, and serving utensils.

Procedures

The production of *E. cottonii* red seaweed pudding is carried out through eight (8) stages, modified based on standard seaweed processing formulations, as follows (Rosyida & Ahmadi, 2022; Spence et al., 2019):

Stage 1

Initial Washing. Fresh red seaweed is thoroughly washed using running water to remove dirt, sand, and salt adhering to the surface of the thallus. The washing process is repeated until the rinse water runs clear.

Stage 2

Soaking. The seaweed is soaked in clean water overnight (approximately 8–12 hours) to reduce the fishy odor and soften the texture of the thallus. This soaking process also helps reduce excess salt content in the seaweed.

Step 3

Re-washing. After soaking, the seaweed is washed again thoroughly in running water to ensure no residual dirt or odor remains.

Step 4

Boiling in Coconut Water. The cleaned seaweed is boiled in fresh coconut water. Coconut water is chosen as the boiling medium to impart natural flavor, enhance the product's nutritional value, and utilize the minerals and antioxidants it contains. Palm sugar and/or white sugar may also be added at this stage as a sweetener, according to preference.

Step 5

Preparing the Base Layer. Biscuits are crushed into fine crumbs and mixed with melted butter. The biscuit and butter mixture is pressed into the mold to form the base layer of the pudding.

Step 6

Pouring the Seaweed Agar. The boiled seaweed agar mixture is poured into the container already holding the biscuit base layer. It is poured slowly to avoid dislodging the biscuit layer.

Step 7

Cooling (Setting). The container holding the pudding is left at room temperature until it sets completely. Subsequently, it can be placed in the refrigerator to accelerate the cooling process and improve the product's texture.

Step 8: Adding Toppings. Once the pudding has set, pour vla over the surface. Add toppings such as white seaweed and fruits according to preference. The product is ready to serve.

RESULTS AND DISCUSSION

Results



Figure 1. Red seaweed *(E. cottonii)* pudding.

The *E. cottonii* red seaweed pudding produced features a distinctive physical characteristic: an attractive reddish-purple hue derived from phycoerythrin, a natural pigment found in the red seaweed. This color provides a unique visual appearance and enhances the product's appeal as a functional food. In terms of texture, the product possesses a firm yet tender consistency, a result of the carrageenan content in *E. cottonii*. The seaweed's characteristic aroma typically quite strong has been modified to be milder and more pleasant by using coconut water as the boiling medium. This combination yields sensory characteristics that are more acceptable to consumers(Anggriani et al., 2022).

Furthermore, the biscuit base introduces a contrasting textural variety a blend of a crunchy yet slightly soft bottom layer and a springy pudding layer on top. This combination creates a more complex sensory experience and enhances the product's overall appeal. Heating may affect the compounds contained in *E.cottonii* but they will not completely disappear or be degraded. Based on a literature review of the composition of *E. cottonii*, it contains the major bioactive compounds listed in Table 1.

Table 1. Bioactive compounds in *E. cottonii* and their biological activities.

Bioactive Compounds	Biological activities	References
Carrageenan	Anti-inflammatory, antimicrobial, anticoagulant	(Salam et al., 2024; Susanti et al., 2024)
Phycoerythrin	Antioxidants, bioactive pigments	(Lumbessy et al., 2020)
β-Carotene	Anti-free radical activity	(Pratita et al., 2023)
Notatic acid	Anti-oxidant	(Fitria et al., 2026)
Cis-piceid		
Campesterol	Anti-inflammatory, Antioxidants, Anti-hyperlipidemia	(Fasya et al., 2019)
Stigmasterol		
β-sitosterol		

Discussion

The red seaweed *E. cottonii* contains significant amounts of phenolic compounds and flavonoids, which act as primary antioxidants. These compounds function by donating hydrogen atoms or electrons to free radicals, thereby halting oxidative chain reactions that could potentially damage cells (Loho et al., 2021). The previous research also proved that the ethanolic extract of *E. cottonii* has an IC_{50} value of 559.76 µg/mL against DPPH free radicals, suggesting moderate antioxidant activity (Arsianti et al., 2020).

In addition to flavonoids and phenolics, the pigment phycoerythrin which gives *E. cottonii* its characteristic red color also exhibits antioxidant activity. It was reported that *E. cottonii* possesses the highest phycoerythrin content, 42.88 mg/g, among Eucheuma species (Lumbessy et al., 2020). Furthermore, the β-carotene content in red algae is known to exhibit anti-free radical activity, with an IC_{50} value of 267.375 ppm (Pratita et al., 2023) thereby contributing to its overall antioxidant activity.

Premature aging is triggered by the accumulation of oxidative stress that damages the skin's structural components, particularly collagen (Rostkowska et al., 2023). The enzyme collagenase plays a role in collagen degradation; therefore, inhibiting this enzyme is a key strategy for preventing aging (Geeta et al., 2019). In her 2021 study, Fitriyah demonstrated that silver nanoparticles synthesized using *E. cottonii* extract exhibit collagenase-inhibiting activity, thereby offering the potential to slow down the process of collagen degradation in the skin.

A study also reported that *E. cottonii* extract from Lampung Bay contains mycosporine-like amino acids (MAAs) and exhibits a maximum SPF value of 20.18 ± 0.99 (categorized as ultra-protection) when using a 25% ethanol extract (Anggraeni et al., 2026). These findings indicate that the consumption of *E. cottonii*-based products not only provides systemic antioxidant benefits but also offers potential protection against skin damage caused by UV exposure. Furthermore, *E. cottonii* extract demonstrates in vivo wound-healing activity in mice, a property correlated with its ability to support tissue regeneration and inhibit skin aging processes (Teo et al., 2021).

Nutritionally, *E. cottonii* contains carbohydrates (47.36%), fiber (15.22%), fat (5.77%), and various essential vitamins and minerals (Lumbessy et al., 2020). *E. cottonii* exhibits the highest protein content (9.76% DW) among the seaweeds (Matanjun et al., 2009). Its high fiber content plays a crucial role in digestive health, blood sugar regulation, and cholesterol control. Carrageenan, the primary component of the *E. cottonii* cell wall, acts as a natural gelling agent that imparts a chewy texture to pudding products while also possessing anti-inflammatory and antimicrobial properties (Salam et al., 2024; Susanti et al., 2024).

The addition of coconut water as the boiling medium in this formulation represents an innovation that significantly enhances the product's functional value. Coconut water contains natural electrolytes, minerals, vitamins, and antioxidant compounds(Bose et al., 2026; Mu et al., 2024). The combination of *E. cottonii's* bioactive compounds and coconut water creates a functional food product that works synergistically to combat free radicals. Previous research has also demonstrated that *E. cottonii* consumption can exert a protective effect against tumor growth, making this product not merely a refreshing dessert but also one with therapeutic value (Shamsabadi et al., 2013).

Implications

The findings of this study have several potential implications for the development of marine-based functional foods. First, the successful incorporation of *E. cottonii* into a pudding formulation demonstrates that red seaweed can be transformed from a conventional raw or semi-processed marine commodity into a more accessible ready-to-consume food product. The reddish-purple color, firm yet tender texture, and reduced seaweed odor obtained through coconut-water processing indicate that the formulation has potential for improving product appeal and consumer acceptance.

Second, the reported presence of phenolics, flavonoids, phycoerythrin, β-carotene, and carrageenan provides a scientific basis for considering *E. cottonii* pudding as a potential antioxidant-oriented functional food. These compounds have been associated with free-radical scavenging and other biological activities, including collagenase inhibition and photoprotective effects. However, these implications should be interpreted as potential functional benefits rather than confirmed health effects of the formulated pudding because the present study did not quantitatively measure the concentration or bioavailability of these compounds in the final product.

From a food innovation perspective, the product may also contribute to increasing the added value of locally cultivated Indonesian seaweed by expanding its applications beyond conventional industrial processing. Further optimization of the formulation could support the development of functional food products with improved nutritional quality, sensory characteristics, and commercial potential.

Research contribution

The study further integrates product development with evidence from previous research regarding the antioxidant, anti-radical, collagenase-inhibitory, photoprotective, antimicrobial, and tissue-regenerative properties associated with *E. cottonii*. This provides a conceptual basis for positioning red seaweed pudding as a marine-derived functional food with potential relevance to oxidative-stress management and healthy aging.

Importantly, this research establishes a foundation for subsequent experimental investigations. The developed product can serve as a prototype for future studies examining its antioxidant capacity, phytochemical composition, nutritional profile, sensory acceptance, physicochemical stability, and biological effects. Thus, the contribution of the present work lies primarily in demonstrating the feasibility of converting *E. cottonii* into an innovative functional food and identifying a research pathway for validating its proposed health benefits.

Limitations

Although the literature indicates that *E. cottonii* has antioxidant, collagenase-inhibitory, photoprotective, and wound-healing activities, these findings cannot be directly extrapolated to demonstrate that consumption of the developed pudding prevents premature aging in humans. The relationship between consumption of the formulated product, bioactive compound bioavailability, systemic antioxidant effects, and anti-aging outcomes requires direct experimental validation.

Suggestions

Future research should prioritize quantitative characterization of the developed *E. cottonii* pudding to establish its functional properties scientifically. Antioxidant activity should be directly evaluated using validated assays such as DPPH, ABTS, and FRAP, accompanied by determination of

total phenolic and flavonoid contents. Quantification of specific bioactive compounds, particularly phycoerythrin and β-carotene, would further clarify their contribution to the antioxidant capacity of the final product.

Further studies should also evaluate the effects of processing conditions, particularly soaking and boiling in coconut water, on the retention and stability of bioactive compounds. Optimization of seaweed concentration, sweetener level, coconut-water proportion, and other formulation components could be performed to identify the optimal balance between functional properties and sensory acceptability

CONCLUSION

The innovation of *E. cottonii* red seaweed pudding as a functional food holds great potential as an antioxidant-rich product capable of neutralizing free radicals and delaying premature aging. Its key bioactive compounds phycoerythrin, β-carotene, carrageenan, notatic acid, cis-piceid, campesterol, stigmasterol, and β-sitosterol offer comprehensive health benefits, ranging from antioxidant activity, collagenase enzyme inhibition, and photoprotection to antimicrobial properties. Further research is required to quantitatively evaluate antioxidant content, conduct structured organoleptic testing and proximate analysis, and perform clinical trials on the formulated *E. cottonii* pudding product to scientifically confirm its functional claims.

ACKNOWLEDGMENT

The author would like to thank the Faculty of Pharmacy, Hang Tuah University for the laboratory facilities and research resources provided during the conduct of this research. The author also thanks all those who have helped, either directly or indirectly, in the completion of this research and the writing of this article.

AUTHOR CONTRIBUTION STATEMENT

MAN: Supervision, Conceptualization, Writing – Review & Editing; AS, AA, AZ, AS, BG, MP, MAG, NP, NM: Investigation, Resources, Writing – Original Draft Preparation.

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