International Journal of Entrepreneurship and Management Practices
IJEMP
EISSN : 2600-8750
Volume 8 Issue 29 (March 2025) PP. 512-522
DOI: 10.35631/IJEMP.829034

INTERNATIONAL JOURNAL OF ENTREPRENEURSHIP AND MANAGEMENT PRACTICES (IJEMP)
www.ijemp.com

A SHORT REVIEW ON THE NUTRITIONAL VALUES, COMMERCIALIZATION OPPORTUNITIES AND CONSERVATION STATUS OF *CLADOSIPHON OKAMURANUS*

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International Journal of Entrepreneurship and Management Practices
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DOI: 10.35631/IJEMP.829034

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Article Info:

Article history:
Received date: 30.01.2025
Revised date: 17.02.2025
Accepted date: 20.03.2025
Published date: 30.03.2025

To cite this document:

Suffian, A. S., Zulfikhar, H., Ismail, M. K., Fauzi, M. U. M., Kamaruddin, S. A., Aziz, K. N. A., Hashim, A. R., Zulkarnain, S. H., Ikhsan, N., Nawi, A. S., Mohammed, R., Joseph, H., Rubama, A., Nazir, E. N. M., & Fauzi, S. S. M. (2025). A Short Review On The Nutritional Values, Commercialization Opportunities And Conservation Status Of *Cladosiphon Okamuranus*. *International Journal of Entrepreneurship and Management Practices, 8* (29), 512-522.

DOI: 10.35631/IJEMP.829034

Abstract:

Cladosiphon okamuranus (C. okamuranus), commonly known as Okinawa mozuku, is a brown seaweed species with significant economic and nutritional importance, particularly in East Asian countries. It is widely distributed in the subtropical waters of the Okinawa region in Japan. This seaweed is characterized by its unique, thread-like structure and has been recognized for its high content of valuable nutrients, including fucoidan, a sulfated polysaccharide known for its potential health benefits. The nutritional values of *C. okamuranus* are diverse; it is a rich source of minerals, vitamins, and dietary fibre, making it a beneficial addition to various diets. Its commercialization opportunities are expanding due to its growing popularity as a health food and its potential use in pharmaceuticals and cosmetics. However, the conservation status of *C. okamuranus* is a concern. Overharvesting, habitat destruction, and climate change pose threats to its natural populations. Sustainable harvesting practices and aquaculture development are crucial for preserving this species and ensuring its availability for future generations. In summary, *C. okamuranus* offers promising nutritional and commercial prospects, but its sustainability must be carefully managed to prevent depletion and ensure its long-term viability.

Keywords:

Cladosiphon Okamuranus, Metabolic, Mozuku, Nutritional, Seaweed

Introduction

Cladosiphon okamuranus (*C. okamuranus*), a type of edible seaweed belonging to the Chordariales order of Phaeophyceae, is commonly referred to as Okinawa mozuku in Japanese (Awanthi et al., 2023). Fishermen's associations in Onna and Chinen Villages on Okinawa have been growing *C. okamuranus* for over many years (Omoto et al., 2024). Various strains of *C. okamuranus* have been developed through cultivation, all of which have similar appearance and texture (Nishitsuji et al., 2020). In 2006, the Japanese Cabinet Office's 36th annual report indicated that the production of approximately twenty kilotons of mozuku (*C. okamuranus* and

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N. decipiens, commonly referred to as "Itomozuku") generated over four billion Japanese yen. The cell-wall matrix of brown algae contains fucoidan, a sulfated polysaccharide having anticoagulant, anti-thrombin-like, and tumor-suppressive effects. Fucoidan is derived from *C. okamuranus* and *N. decipiens*. Brown algae also produce alginates (Nishitsuji et al., 2016).

Metabolic illnesses like obesity, diabetes, and high cholesterol are increasing in frequency because of the growing consumption of high-calorie, low-fibre diets. These illnesses can result in major health issues, such as heart disease, which is the leading global cause of mortality. Identifying natural food treatments that can help control these ailments is becoming more and more intriguing. Research has shown that the indigestible dietary fibre in *C. okamuranus*, an edible brown alga, can aid of the prevention and alleviation of constipation (Yang et al., 2022). 99% of *C. okamuranus* is produced in Okinawa, almost entirely farmed by humans (Figure 1).

Figure 1: *C. okamuranus* Farm

Source: (Sudo, 2016)

C. okamuranus is native to the Ryukyu Islands of Japan and is valued for its culinary applications. The molecular subtleties of this species have been illuminated by recent developments in genome decoding. Previous studies have investigated its potentially anti-inflammatory, antiviral, and anticancer characteristics, suggesting that it may influence humoral and cellular immunity. Significant improvements in macrophage phagocytosis, interleukin (IL)-2 levels, immune cell proliferation, and serum antibody concentrations (IgM, -G, -A) are observed, along with noteworthy reductions in IL-4, -5, and IgE. These results point to the possibility of modulating humoral and cellular immunity with fucoidan produced from *C. okamuranus* (Tomori et al., 2019). However, there is insufficient information available on *C. okamuranus*. This review focuses on the distribution, features, nutritional values, marketing potential, and conservation status of *C. okamuranus*.

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Methodology

The data collection for this manuscript entailed the methodical extraction of information from electronic databases, namely Google Scholar (https://scholar.google.com/), PubMed (https://pubmed.ncbi.nlm.nih.gov/), Scopus (https://www.scopus.com/), and ResearchGate (https://www.researchgate.net) (Shaik Farid et al., 2024). The search queries utilized in these databases incorporated keywords such as *Cladosiphon okamuranus*,' 'distribution of *C. okamuranus*,' 'health benefits of *C. okamuranus*,' 'medical properties of *C. okamuranus*,' 'ecology of *C. okamuranus*,' 'commercialization of *C. okamuranus*,' 'phytoremediation in *C. okamuranus*,' and 'Conservation status of *C. okamuranus*.

Findings

Distribution of Cladosiphon Okamuranus

C. okamuranus, is native to the Ryukyu islands, particularly in Okinawa prefecture, Japan. Okinawa islanders have embraced it as a staple food, making it a significant part of the native diet (Kadena et al, 2018). Research has been conducted to explore the health benefits associated with consuming *C. okamuranus* because to its unique regional distribution and dietary habits, specifically focusing on the absorption of fucoidan, a bioactive compound found in this seaweed.

The species of *C. okamuranus*, is indigenous to the Ryukyu archipelago, confined to the region between the southern limit (24° N) of the Yaeyama Islands in Okinawa prefecture and the northern limit (29° N) of Amami Island in Kagoshima prefecture (Figure 2) (Sudo et al., 2022). This limited geographical distribution makes *C. okamuranus* a distinctive and culturally significant resource for the people of Okinawa.

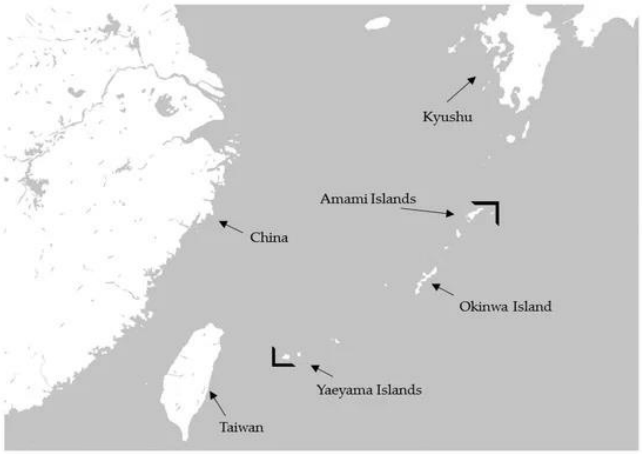

Figure 2: Geographical distribution of Okinawa Mozuku (*C. okamuranus*)
Source: (Kadena et al, 2018)

C. okamuranus eating is a significant part of the dietary traditions of the Okinawan people. *C. okamuranus* is a traditional and popular delicacy that is often used in local cuisine. Volunteers in Okinawa prefecture consume *C. okamuranus* more frequently than those in other regions. A study conducted among Japanese volunteers has shown a correlation between dietary habits and the absorption of fucoidan, a bioactive component present in *C. okamuranus* (Kadena et al, 2018).

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Characteristics of Cladosiphon Okamuranus

C. okamuranus, with unique characteristics that has been extensively studied. Okinawa, Japan mostly cultivates it for food (Nishitsuji, et al, 2020). The sporophytes look like fronds and their main axes range in diameter from 2 to 5 mm. The predominant strain used in cultivation is the S-strain, characterised by lengthy lateral branches and a non-fibrous body (Nishitsuji, et al, 2020).

Physical Characteristic

As it grows older, *C. okamuranus* displays unique physical characteristics. Older thalli feel tougher and have a deeper hue than younger thalli, which are stickier or slimier to the touch (Miwa et al., 2023). The main shaft and lateral branches of elderly thalli had a much higher breaking strength than those of juvenile thalli, as demonstrated by quantitative measurements of this strength differential (Miwa, et al., 2023). Furthermore, it was found that the primary axis of both young and old thalli had identical anatomical characteristics and were hollow.

Chemical Composition

During growth, the *C. okamuranus* cell wall's composition varies, especially in terms of the proportions of its two primary constituents, hemicellulose-I (HC-I) and hot water (HW) (Sudo et al., 2022). In older thalli, the production of HC-I rose while the yield of HW fell, suggesting a change in the cell wall's structure during growth (Miwa, et al., 2023). Moreover, it was proposed that HC-I had a major effect on the strength of thalli during growth. Differences in moisture content and yield were observed between the two age groups in the alcohol-insoluble residues (AIRs) yields that were extracted from young and old thalli (Miwa, et al., 2023).

Potential Applications

Because of its distinct traits and chemical composition, *C. okamuranus* is a promising research subject with potential uses in many different sectors. As per Miwa et al. (2023), an abundant source of fucoidan, a form of cell wall polysaccharide, is found in algae. This polysaccharide is of interest due to its potential biological activity and industrial applications. Comprehending the alterations brought about by growth in *C. okamuranus* 's cell wall polysaccharides may have consequences for biotechnological and medicinal uses.

Cell Wall Polysaccharides

Complex carbohydrates known as cell wall polysaccharides are present in the cell walls of a wide range of species, including bacteria, fungi, algae, and plants (Awanthi, et al, 2023). These polysaccharides are crucial for some physiological functions, including cell growth, development, and defence against external stressors, as well as for preserving the structural integrity of the cell wall (Awanthi, et al, 2023). *C. okamuranus* 's cell wall polysaccharides were fractionated and characterized. This process provided information about the structural variations and cell wall localization of these polysaccharides, as well as functions and uses (Awanthi, et al, 2023). Given the circumstances, research on the cell wall polysaccharides found in brown algae and other species is crucial and has ramifications for some industries, including biotechnology, medicine, and agriculture.

Fucoidan

C. okamuranus 's cell walls include fucoidan, a sulfated polysaccharide that is also present in the cell walls of certain other marine creatures including sea cucumbers and sea urchins. Its structure can change based on the type of algae and the growing environment. It is made up of

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a complicated mixture of fucose, sulfate, and other monosaccharides (Fitton, 2011). Numerous biological actions of fucoidan have been demonstrated, such as anti-tumour, anti-coagulant, anti-thrombin-like, and anti-inflammatory properties (Ale et al., 2011). It has also been demonstrated to have potential uses in the creation of novel medications and treatments for a variety of illnesses, including viral infections, cancer, and cardiovascular disease (Cumashi, et al, 2007). Fucoidan has potential medicinal uses as well as uses in the food and cosmetic industries as an emulsifier and gelling agent as well as a moisturizer and anti-aging agent (Kim & Wijesekara, 2011). Furthermore, recent study by Hwang et al., (2024) showed that fucoidan from *C. okamuranus* enhances antioxidant activity and prevents reproductive dysfunction in polystyrene microplastic-induced male rats.

Nutritional Value of Cladosiphon Okamuranus

C. okamuranus, is renowned for its impressive nutritional profile and potential health benefits. This marine alga is rich in essential nutrients, making it a valuable addition to a balanced diet. One of the standout nutritional features of *C. okamuranus* is its high content of dietary fibre. Fiber is crucial for digestive health, promoting regular bowel movements and preventing constipation (Tomori et al., 2019). *C. okamuranus* also contains a variety of vitamins and minerals, including vitamin C, calcium, iron, and magnesium. Vitamin C is essential for immune system support, while calcium and magnesium contribute to bone health and overall well-being. Additionally, the presence of iron in *C. okamuranus* is beneficial for individuals with iron-deficiency anemia (Nagamine er al., 2020).

Furthermore, *C. okamuranus* is a notable source of fucoidan, a unique compound with potential health-promoting properties. Fucoidan has been studied for its anti-inflammatory, anti-viral, and anti-cancer effects, although more research is needed to fully understand its mechanisms and potential therapeutic applications (Li et al., 2023). Beyond its nutritional content, *C. okamuranus* is prized for its umami flavour, contributing a savoury and distinct taste to various dishes. It is commonly used in salads, soups, and pickles, showcasing its versatility in Japanese cuisine.

While *C. okamuranus* offers numerous health benefits, individuals with allergies to seafood or seaweed should exercise caution. Additionally, it is advisable to consume *C. okamuranus* as part of a diverse and balanced diet to maximize its nutritional advantages. Incorporating this nutrient-rich seaweed into one's culinary repertoire not only adds a unique taste to meals but also contributes to overall well-being (Kim et al., 2024).

Commercialization Opportunities of Cladosiphon Okamuranus

Seaweeds have gained popularity recently as nutritious meals with advantageous ingredients that may help prevent and treat diseases linked to an unhealthy lifestyle. Thus far, extracts of *C. okamuranus* have been reported to exhibit anticancer (Nagamine et al., 2019, Zorofchian Moghadamtousi et al., 2014), antioxidative (Reddy et al., 1984), antiviral (Trejo-Avila et al., 2016), antiatherogenic (Zhang et al., 2024), immunostimulatory (Jeong et al., 2006, Oomizu et al., 2006), and anti-inflammatory (Shiratori et al., 2005) effects. Irrational eating habits and the contemporary propensity for high-nutrient diets have led to the rise of lifestyle-related illnesses like diabetes and obesity. *C. okamuranus*, is a marine meal that has the potential to be both delicious and medicinal. *C. okamuranus* is well known for having a high nutritional profile and for having important vitamins, minerals, and dietary fibres. Its high concentration of the sulfated polysaccharide fucoidan—which has been researched for its anti-inflammatory,

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antiviral, and anticancer effects—is especially noteworthy. The antioxidant components of *C. okamuranus* enhance the health of cells, and its immunomodulatory properties indicate advantages for the immune system. *C. okamuranus* is a promising marine food source, with potential effects on cardiovascular health, gastrointestinal health, and potentially antiviral protection. Its incorporation into the diet may boost collagen synthesis, anti-inflammatory properties, and bone health, providing a comprehensive strategy for enhancing health and wellbeing.

Conservation Status of Cladosiphon Okamuranus

C. okamuranus, has faced conservation issues due to environmental changes, overharvesting, and other factors. It is subject to variations in water temperature and pollution, as do other marine species, raising worries about the sustainability of its wild populations. According to Uruma (2021), news item from Ryukyu Shimpo, Japan's *C. okamuranus* supply is being impacted by large quantities of pumice stones floating in the ocean. Measures have been taken to protect and preserve this significant seaweed species.

To accommodate the increased demand for *C. okamuranus* while also addressing conservation concerns, a considerable shift toward aquaculture has occurred (Higa et al, 2022). Because of its adaptation to regulated circumstances and fast development rate, *C. okamuranus* is a desirable species for aquaculture. The Okinawa Mozuku Aquaculture Promotion Committee reported that the total production of *C. okamuranus* in 2021 was 19,278 tonnes. The Katsuren Cooperative was the top producer with 8,299 tonnes, followed by the Chinen Cooperative with 3,148 tonnes. *C. okamuranus* aquaculture is critical to the preservation and protection of wild populations. The cultivation of *C. okamuranus* in controlled circumstances reduces the burden on natural habitats, so preserving biodiversity and reducing the loss of wild stocks. Conservation methods for *C. okamuranus* need to be a priority for all parties to ensure that this species lives sustainably. The use of technology such as Geographic Information Systems with spatial interpolation methods can be used to map the relationship between potential pollutants and the ecology of *C. okamuranus*'s life (Kamaruddin et al., 2022). Marine water quality studies can also be conducted to detect potential impacts on the habitat and life cycle balance of this species (Kamaruddin et al., 2018). Figure 3 shows yearly harvest amount of three types of Mozuku: *C. okamuranus*, *N. decipiens* and Onna-Mozuku, respectively.

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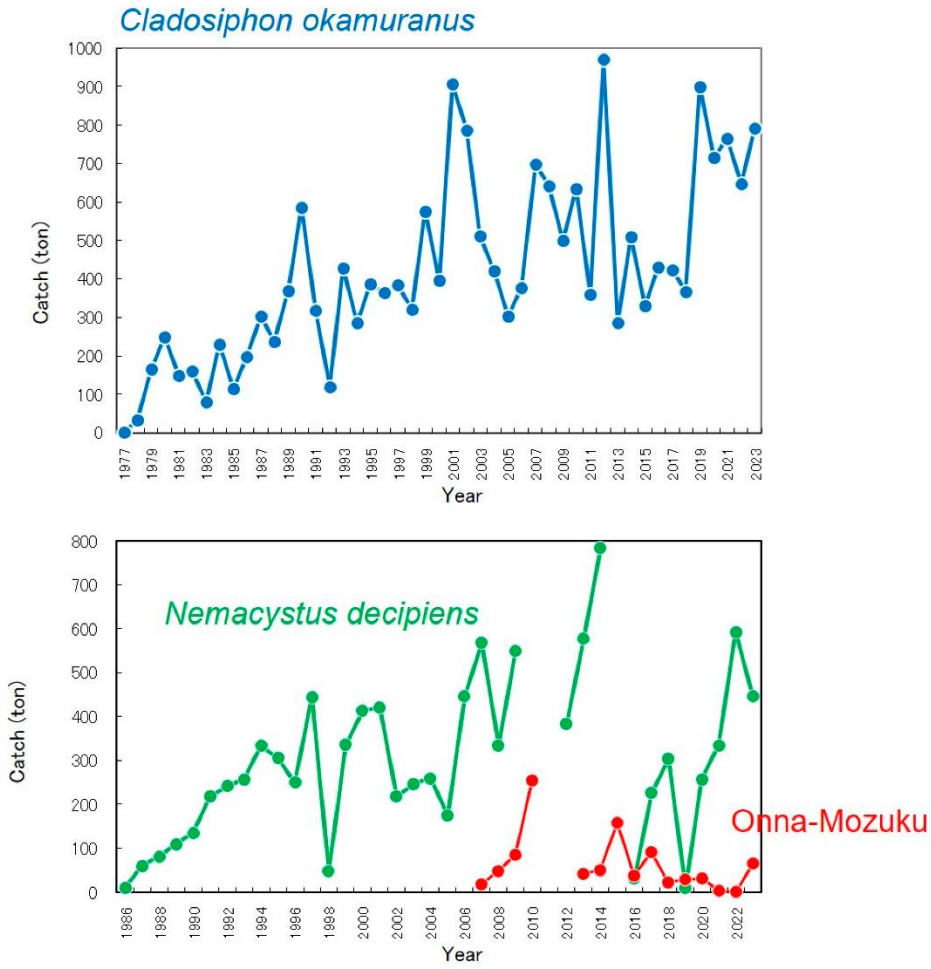

Figure 3: Yearly Harvest Amount Of Three Types Of Mozuku

Source: (Omoto et al., 2024)

Conclusion

In summary, this review of *C. okamuranus*, commonly referred to as Okinawa mozuku, has illuminated its noteworthy range, distinct traits, remarkable nutritional value, growing commercialization potential, and worrisome conservation status. This brown seaweed species' abundance of fucoidan, vital minerals, and dietary fibre makes it extremely promising for a variety of businesses, including food, medicine, and cosmetics. However, overharvesting, habitat damage and climate change pose a threat to the sustainability and conservation of *C. okamuranus*. For this important species to remain viable eventually, it is imperative that these issues are resolved.

Recommendation

To support sustainable use and conservation efforts, conduct a thorough analysis of the distribution, traits, nutritional value, commercialization potential, and conservation status of the seaweed species *C. okamuranus*. A detailed analysis of the distribution, traits, nutritional value, commercialization potential, and conservation status of *C. okamuranus* is essential, given its commercial and ecological relevance. This review will offer insightful information about the species, facilitating well-informed choices and successful management plans.

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It is important to include information about *C. okamuranus*'s development habits, habitat needs, nutritional makeup, and possible industrial uses in the review. It should also assess the species' present state of conservation, considering potential risks and the effectiveness of current conservation efforts. Stakeholders can obtain a thorough understanding of *C. okamuranus*, including its ecological significance and potential as a commercial resource, by performing this review. The results will direct the development of aquaculture methods, conservation initiatives, and sustainable harvesting practices. Moreover, this information can be utilized to encourage public participation in and understanding of *C. okamuranus* conservation initiatives.

Acknowledgments
We also want to thank Universiti Teknologi MARA and the University of Ryukyus for Sakura Science Exchange Program support (600-TNCPI/PBT 5/3 INT (074/2023))

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International Journal of Entrepreneurship and Management Practices
IJEMP
EISSN : 2600-8750
Volume 8 Issue 29 (March 2025) PP. 512-522
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