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Seaweed-Based Bioactive Compounds in Aquaculture

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ABSTRACT

Aquaculture become the fastest-growing sector in the world. Out of 223.3 million metric tonnes of total fisheries and aquaculture production, seaweed contribution is about 36.5 million tonnes. Many varieties of seaweeds are now cultured worldwide with species including red seaweed (e.g., Gracilaria, Porphyra), brown seaweed (e.g., Laminaria, Ascophyllum), and green seaweed (e.g., Ulva, formerly Enteromorpha), these species are mainly utilized for the production of many bioactive compounds like Agar, Carrageenan, Alginic acid, polyphenols etc. these products are mainly used in biotechnology, media preparation, preparation of ice-creams and jellies etc. This article discusses the importance and use of seaweed-based bioactive compounds in aquaculture.

INTRODUCTION

The human population now depends exclusively on aquaculture for its seafood needs, and this industry plays a major role in ensuring the world's food security. Due to population increase and diminishing wild fish supplies, there is a growing demand for nutrient-dense seafood and aquaculture has assisted in balancing the supply and demand. As a result, experts studying aquaculture around the world are searching for more reasonably priced and health-promoting feed ingredients that can support fish growth and guard against illness in aquaculture operations (Garlock *et al.*, 2022).

Given their favourable nutritional composition, environmental sustainability and potential health-promoting factors for farmed fish, there has been an increasing interest in using various seaweeds, such as red seaweed (e.g., Gracilaria, Porphyra), brown seaweed (e.g., Laminaria, Ascophyllum), and green seaweed (e.g., Ulva, formerly Enteromorpha), as potential sources of bioactive compounds and feed ingredients for inclusion in aquafeed in recent years (Afewerki *et al.*, 2024).

Furthermore, compared to animal-derived protein, the manufacturing of vegetable proteins uses less water, land, nitrogen and fossil fuel. Freshwater or saltwater organisms are included in aquaculture, which is a general word that covers a wide range of rearing circumstances and techniques. The amount of aquaculture produced worldwide has steadily expanded, rising from 71.9 million tons in 1980 to 214 million tons in 2022-23 (FAO, 2024). This industry is growing at a particularly rapid rate in many developing nations where aquaculture may eventually replace capture fisheries as the primary source of seafood. China is the world's largest producer of aquaculture, mostly in freshwater aquaculture, with India coming in second. On the one hand, the consumption of aquatic products is thought to have a number of health benefits. As a result, the production of various edible marine species for human consumption through aquaculture techniques has increased recently, resulting in a large volume of by-products from fish processing (FAO, 2024).

Therefore, one of the goals of marine pharmaceuticals, a new field of pharmacology that has emerged in recent decades, is the incorporation of seaweed chemicals for the synthesis of novel natural medications. Alginate, carrageenan, agar, carotenoids, and polyphenols are among the many bioactive substances found in seaweeds. These compounds have a variety of biological properties, including antibacterial, anti-inflammatory, antioxidant and antidiabetic properties. In conclusion, when it comes to harvesting microalgae, throughout the past few decades, the market for healthy foods has been the primary use for them, with over 75% of the yearly production of microalgal biomass going toward the production of powders, tablets, capsules, or pills (Abu-Ghannam and Rajauria, 2013).

Bioactive Compounds and their uses

1. Agar

Agar is a jelly-like substance that's extracted from the cell walls of red algae, such as ogonori (Gracilaria) and tengusa (Gelidiaceae). It's a mixture of two polysaccharides, agarose and agaropectin, and is used in many industries because of its ability to form gels.

Agar is a seaweed PS that gels firmly and has hydrocolloidal characteristics. A low ester sulphate content and the repeating units of D-galactose and 3,6-anhydro-L-galactose, with a few variations, characterize the main structure of agar chemically. Agarose, a neutral PS, and agaropectin, an oversimplified term for the charged PS, make up the two groups of PSs that make up agar.

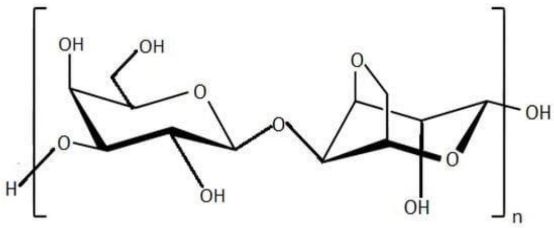


Figure 1. Chemical structure of agarose polymer

2. Carrageenan

Primarily present in red algae, carrageenan is a linear polysaccharide (PS) composed of sulphated or non-sulphated galactose units that are connected by α-1,3-glycosidic linkages and β-1,4-galactose links. In nature, carrageenans exist as hybrids made up of different nonhomologous polysaccharides. Carrageenans are therefore classified into three major fractions (κ-carrageenan, ι-carrageenan, and λ-carrageenan) and four minor fractions(ι carrageenan, v-carrageenan, ξ-carrageenan, and µ-carrageenan) based on the principal repeated disaccharide unit and the position at which the sulphate group is connected on the galactose unit.

Natural polysaccharide carrageenan is derived from red, edible seaweeds and possesses thickening, stabilizing, and gelling qualities. It helps shrimp develop and stay healthier in aquaculture. Natural polysaccharide carrageenan is derived from red, edible seaweeds and possesses thickening, stabilizing, and gelling qualities. It helps shrimp develop and stay healthier in aquaculture. Natural polysaccharide carrageenan is derived from red, edible seaweeds and possesses thickening, stabilizing, and gelling qualities. It helps shrimp develop and stay healthier in aquaculture.

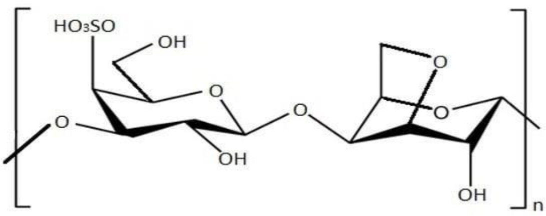


Figure 2. Chemical structure of κ-carrageenan

3. Alginate

Red, edible seaweeds are the source of the natural polysaccharide carrageenan, which has thickening, stabilizing, and gelling properties. It promotes the growth and well-being of shrimp raised for aquaculture. Red, edible seaweeds are the source of the natural polysaccharide carrageenan, which has thickening, stabilizing, and gelling properties. It promotes the growth and well-being of shrimp raised for aquaculture. Red, edible seaweeds are the source of the natural polysaccharide carrageenan, which has thickening, stabilizing, and gelling properties. It promotes the growth and well-being of shrimp raised for aquaculture (Balasubramanian *et al.*, 2006).

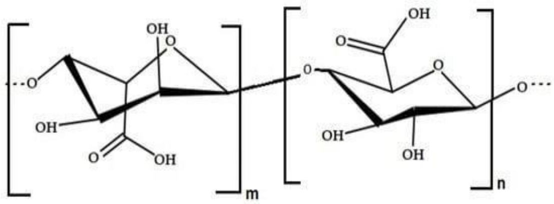


Figure 3. Chemical structure of alginic acid

4. Laminarin

The naturally occurring polysaccharide carrageenan, which has thickening, stabilizing, and gelling qualities, is derived from red, edible seaweeds. The development and health of shrimp farmed for aquaculture are enhanced by it. The naturally occurring polysaccharide carrageenan, which has thickening, stabilizing, and gelling qualities, is derived from red, edible seaweeds. The development and health of shrimp farmed for aquaculture are enhanced by it. The naturally occurring polysaccharide carrageenan, which has thickening, stabilizing, and gelling qualities, is derived from red, edible seaweeds. The development and health of shrimp farmed for aquaculture are enhanced by it.

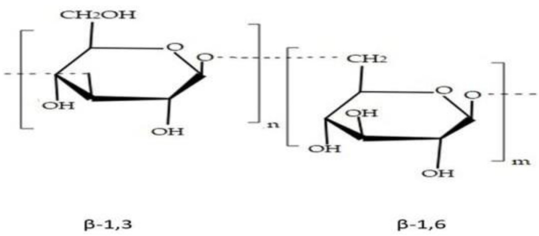


Figure 4. Chemical structure of laminarin

5. Polyphenols

In vitro and in vivo research have demonstrated the antioxidant, antibacterial, antidiabetic, anti-inflammatory, and anticancer effects of polyphenols, which are substances with one or more aromatic rings containing hydroxyl groups. Polyphenols possess antioxidant activity and redox potential, which enable them to mitigate the production of reactive oxygen species (ROS) linked to several human illnesses. There is already antioxidant chemicals made from seaweeds on the market that are beneficial to health or that can extend the shelf life of food (Agregán *et al.*, 2017).

Phlorotannins are the most well-known of the several classes of algal polyphenols because of their potential therapeutic use. Phlorotannins are classified into six distinct groups based on the number of hydroxyl groups present and the variety of structural links between phloroglucinol units (1,3,5-trihydroxybenzene): phlorethols, fuhalols, fucols, fucophlorethols, eckols, and carmalols.

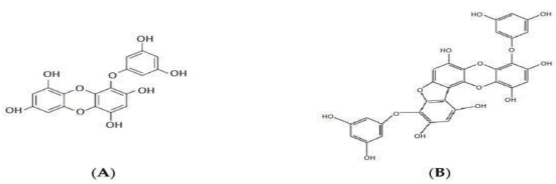


Figure 5. Chemical structure of eckols (A) phlorofucofuroeckol A (B); phlorotannins isolated from *Ecklonia cava*

6. Fucoidan

Exclusive to brown seaweeds are the PSs fucoidan, alginate, and laminarin. Significant amounts of sulfate ester groups and L-fucose are present in fucoidans (Figure 3). Species to species varies in their complicated architecture. In addition to fucose and sulphate, they also contain uronic acids, protein, acetyl groups, and other monosaccharides such as mannose, galactose, glucose, and xylose.

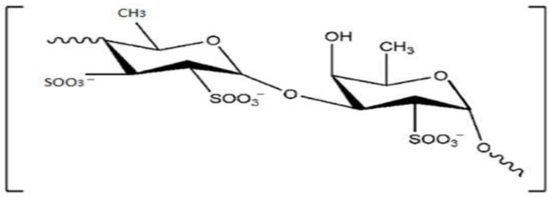


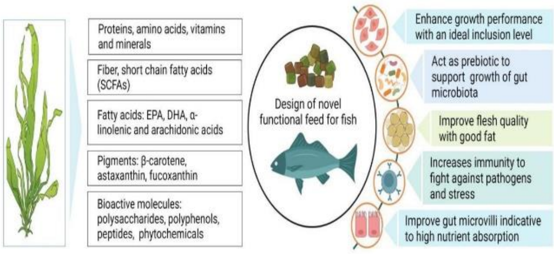
Figure 6. Chemical structure of PS fucoidan

The Role of Seaweed in Aquaculture Production

In addition to the conventional components used in fish aquafeed, seaweed has the potential to be a sustainable and affordable supply of important nutrients. Fish raised in farms can have better development, health, and disease resistance if they eat seaweed, which also helps protect them from invasive pathogens. The majority of the studies covered here focus on the use of seaweed and seaweed-based extracts in fish nutrition because there is a lack of information about the use of seaweed functional metabolites in aquafeed. Below is a summary of some of the main ways that adding seaweed to aquafeed affects fish output.

1. Growth Performance

The nutritional profile and fish species-specific eating habits have a significant impact on how effective seaweed is as a feed addition. Seaweed may generally be added to diets at modest levels—up to 10%—and has been demonstrated to significantly enhance growth, feed utilization, and nutrient absorption. It has been demonstrated that adding Laminaria sp. to the diet at levels of 3 and 10% greatly increases the amount of feed that Atlantic salmon consume on a daily basis and increases their weight (Barasa *et al.*, 2022). Similarly, it was shown that adding 0.4% of the polysaccharide fucoidan which is generated from brown algae (*Cladosiphon okamuranus*) to the food considerably enhanced the growth performance of young red sea bream (*Pagrus major*) (Satoh *et al.*, 1987). On the other hand, adding red seaweed (*Porphyra dioica*) to the diet up to 10% did not have any effect on the growth of the fish, but adding it to the diet at 15% significantly reduced the growth of the rainbow trout (*Oncorhynchus mykiss*). It was reported that 10% dietary red alga (*Porphyra dioica*) showed no negative effects on rainbow trout growth, while 15% inclusion showed negative results compared to the control (Cao *et al.*, 2016). In a similar vein, a 6% dietary provision of Gracilaria pygmaea improved the growth performance of O. mykiss, while a 12% inclusion evoked negative impacts on growth. All things considered, these findings suggest that seaweed can either considerably enhance or sustain growth when added at the proper inclusion level. Interestingly, increased concentrations of bioactive components (phytonutrients, or key vitamins and minerals) that are crucial for fish's improved absorption of dietary nutrients are probably responsible for the higher growth seen with seaweed supplemented diets. Interestingly, a variety of polysaccharides and oligosaccharides have also been proposed to be present in seaweed. These substances function as prebiotics, enhancing the activity of beneficial bacteria and improving the digestion and absorption of vital nutrients, ultimately leading to improved fish growth performance (Charoensiddhi *et al.*, 2017).



2. Feed Conversion Ratio (FCR)

FCR remains a fundamental metric to assess feed efficiency in fish, where a lower value represents an improved conversion of feed to fish biomass gain. The reliance on this metric stem from the fact that feed inputs are a major cost for intensive aquaculture operations. Several feed additives, including seaweed, have been incorporated into aquafeed to improve the FCR. Several studies reported that dietary seaweed inclusion resulted in a lower FCR in Nile tilapia, *Salmo salar*, *Pagrus major*, *Acanthopagrus schlegelii*, and *Labeo rohita*. Improvements to FCR could be partly due to the presence of various bioactive compounds (carotenoids, polysaccharides, amino acids, and fatty acids) that significantly improve the palatability and, consequently, intake of feed, hence improving feed utilization (Dawczynski *et al.*, 2007).

It has been demonstrated that bioactive compounds can increase the release of lipase, protease, and amylase, three enzymes that are known to improve the assimilation and digestion of vital nutrients into fish tissues. Similarly, the actions of seaweed's polysaccharides, which decrease feed's passage through the digestive tract and increase nutrient digestion and bioavailability, may contribute to better FCR. Furthermore, the prebiotics included in seaweed may promote the growth of advantageous bacteria in the intestine, which would greatly increase feed efficiency and digestibility.

3. Feed Palatability

One of the most important elements influencing the consumption of feeds by farmed species is the palatability of aquafeed. A decrease in palatability could result in a rise in feed waste, which would lower fish productivity and hurt aquaculture businesses' bottom lines. However, if the nutritional needs of the species are being satisfied, more palatable meals boost feed consumption and effectiveness, which usually leads to better fish growth. However, the nutritional makeup of an aquafeed's constituents, feed processing methods, nutrient digestibility, water stability, species-specific nutritional needs, and fish physiology all have a significant impact on how tasty it is.

Recent research has focused a great deal of attention on the use of various plant-origin protein sources, such as those derived from algal species, to improve the palatability of fish diet. found that when brown seaweed (Laminaria sp.) was added to the diet, the amount of feed taken by Atlantic salmon increased as compared to a control feed that lacked seaweed. In a similar vein, higher intakes of a diet based on Ulva sp. were noted in sea urchins (*Tripneustes gratilla*) and seabreams (*S. aurata*). A number of bioactive substances, including amino acids, peptides, dimethyl-beta-propionthein, and dimethyl sulfonyl propionate, which improve a feed's appeal to farmed fish species and hence raise feed consumption, may be responsible for this increased feed response.

4. Feed Digestibility

The digestibility of the feed elements that make up an aquafeed has a significant impact on its effectiveness. Adding components with a high digestible value can optimize feed consumption and reduce waste, enhancing growth performance. It has been documented that adding up to 20% of Ulva sp. to the diets of Nile tilapia did not affect the apparent nutritional digestibility coefficients (ADC) of protein, fat, or energy. It was discovered that Ulva meal had a higher digestibility in Nile tilapia diets when compared to diets that contained Gracilaria or Porphyra. When compared to a control diet, it was discovered that the addition of Porphyra dioica up to 15% did not cause any appreciable changes in rainbow trout diets. Nevertheless, it has been observed that Ulva rigida replaced 10% of the soybean meal, lowering the ADC of protein in Nile tilapia from 87% to 82%. Interestingly, the impact of seaweed inclusion on nutritional ADC seems to vary on the type of seaweed, the kind of fish species, the makeup of the feed, and the extent to which the studied seaweed is included, so replacing the protein supply. The capacity for digestion and absorption of the nutrients contained in seaweed is determined by gut anatomy, which explains why different seaweed species have differing impacts on the digestibility of nutrients in different fish species. When seaweed is added to the diet, the majority of herbivorous and omnivorous fish species show increased levels of amylase activity, which facilitates a better breakdown of the carbohydrates. Importantly, a lack or restricted quantity of these enzymes causes carnivorous fish species to be less able to break down complex seaweed polysaccharides.

5. Immunity and Disease Resistance

Disease continues to be a major concern to the intensive aquaculture sector, impeding its expansion and possibly resulting in enormous financial losses. Maximizing productivity in a constrained culture period is the primary goal of intensive aquaculture systems. Operating at high stocking densities may sometimes increase on-farm efficiency at the expense of water quality degradation and fish health risks due to immune system suppression and disruption of antioxidant defense mechanisms. Different kinds of medications are frequently utilized for the treatment of disease in order to solve these issues. However, because of their careless usage, there are now rising worries about the effects on the environment and public health from eating treated farmed fish directly or from consuming wild species that are found near treated aquaculture farms. Moreover, the quick use of antibiotics may result in the emergence of germs resistant to them, which would greatly diminish their ability to treat illnesses. Thus, it is crucial to look for preventative methods that are as ecologically friendly as possible. An appropriate substitute is the use of seaweed-based feed components as immunostimulants to boost fish immunological state. It was shown that via modifying the activity of glycoproteins CD3 and CD4, 5% of dietary Gracilaria domingensis (Rhodophyta) enhanced the immunological response of juvenile mullet (Mugil liza). In a similar vein, black sea bream (*Acanthopagrus schelegelii)* showed enhanced antioxidant profile and immunological capacity when fed 6% dietary S. hornei. Similarly, the innate immune response of Nile tilapia was significantly enhanced by the green seaweed Ulva lactuca (previously *Ulva fasciata*) (Chlorophyta) via modifying lysozyme and phagocytic activity, total WBC count, and overall antioxidant status. Similar to this, adding red microalga (Porphyridium sp.) to the pompano (Trachinotus ovatus) diet significantly increased the levels of complement C4 and mRNA c-type lysozyme while decreasing the levels of mRNA heat shock protein (HSP70), which in turn improved nonspecific immune responses.

CONCLUSIONS

Growing amounts of data indicate that supplementing fish with seaweed and functional metabolites produced from it has a significant favourable impact on their growth, resilience to physiological stress, and immune system function. The effects of seaweed supplementation on nutrient digestibility, the possibility of long-term effects on fish health, and the potential interactions between dietary seaweed supplementation and high dietary inclusion levels of terrestrial plant proteins and carbohydrates are among the issues surrounding the use of seaweed that call for further research. In order to clarify the underlying physiological mechanisms of any potential benefits of seaweed and its immunomodulatory chemicals, more research on fish should be done. In order to further this newly emerging field of study and to completely comprehend the commercial potential of seaweed in aquaculture, such research is considered vital. Ultimately, the process of standardizing research parameters and then disclosing critical performance and health indicators for fish will help determine the ideal proportions of seaweed and seaweed-derived bioactive to include in aquafeed for a variety of species. In the end, this will encourage the wider application of seaweed and bioactive obtained from seaweed in aquaculture production in the future.

REFERENCES

Abu-Ghannam N, Rajauria G (2013) Antimicrobial activity of compounds isolated from algae. In: Domínguez H (ed) Functional ingredients from algae for foods and nutraceuticals. Woodhead, Sawston, pp 287–306

Afewerki, S.; Asche, F.; Misund, B.; Thorvaldsen, T.; Tveteras, R. Innovation in the Norwegian aquaculture industry. *Rev. Aquac.* 2023, *15*, 759–771.

Agregán, R.; Munekata, P.E.; Domínguez, R.; Carballo, J.; Franco, D.; Lorenzo, J.M. Proximate composition, phenolic content and in vitro antioxidant activity of aqueous extracts of the seaweeds *Ascophyllum nodosum*, *Bifurcaria bifurcata* and *Fucus vesiculosus*. Effect of addition of the extracts on the oxidative stability of canola oil unde. *Food Res. Int.* 2017, *99*, 986–994.

Balasubramanian G, Sudhakaran R, Syed Musthaq S, Sarathi M, Sahul Hameed AS (2006) Studies on the inactivation of white spot syndrome virus of shrimp by physical and chemical treatments, and seaweed extracts tested in marine and freshwater animal models. J Fish Dis 29:569–572

Barasa, J.E.; Mukhongo, P.N.; Ngetich, C.C. Perspectives on salmon aquaculture: Current status, challenges and genetic improvement for future growth. In

Salmon Aquaculture; IntechOpen: London, UK, 2022; pp. 1–28.

Cao, J.; Wang, J.; Wang, S.; Xu, X. Porphyra species: A mini-review of its pharmacological and nutritional properties. *J. Med. Food* 2016, *19*, 111–119.

Charoensiddhi, S.; Conlon, M.A.; Franco, C.M.M.; Zhang, W. The development of seaweed-derived bioactive compounds for use as prebiotics and nutraceuticals using enzyme technologies. *Trends Food Sci. Technol.* 2017, *70*, 20–33.

Dawczynski, C.; Schubert, R.; Jahreis, G. Amino acids, fatty acids, and dietary fibre in edible seaweed products. *Food Chem.* 2007, *103*, 891–899.

FAO (2022). *The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation*. Rome, FAO. https://doi.org/10.4060/cc0461en

FAO (2024). *The State of World Fisheries and Aquaculture 2024. Blue Transformation in action*. Rome. https://doi.org/10.4060/cd0683en

Garlock, T.; Asche, F.; Anderson, J.; Ceballos-concha, A.; Love, D.C.; Osmundsen, T.C.; Beatriz, R.; Pincinato, M. Aquaculture: The missing contributor in the food security agenda. *Glob. Food Secur.* 2022, *32*, 100620.

Satoh, K.-I.; Nakagawa, H.; Kasahara, S. Effect of Ulva meal supplementation on disease resistance of red sea bream. Bull. *Jpn. Soc. Sci. Fish.* 1987, *53*, 1115–1120.