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Seaweeds as Functional Feed Additives in Aquaculture: Effects on Growth, Immunity and Disease Resistance

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Aquaculture is one of the fastest-growing food production sectors worldwide and plays a crucial role in global food security. However, the increasing demand for sustainable aquafeeds has prompted the search for alternative feed ingredients that can improve fish health and reduce dependence on conventional feed resources. Seaweeds have emerged as promising functional feed additives due to their rich nutritional composition and abundance of bioactive compounds. Seaweeds contain proteins, essential amino acids, polysaccharides, vitamins, minerals, pigments, polyphenols, and fatty acids that contribute to improved growth performance, feed utilization, immune responses, and disease resistance in aquatic organisms. Numerous studies have demonstrated that dietary supplementation with seaweeds such as *Ulva*, *Gracilaria*, *Hypnea*, *Sargassum*, and *Kappaphycus* can enhance specific growth rate, survival, antioxidant capacity, and resistance against bacterial pathogens. Bioactive compounds including fucoidan, laminarin, carrageenan, alginate, ulvan, and phlorotannins act as immunostimulants and antimicrobial agents, making seaweeds valuable alternatives to synthetic growth promoters and antibiotics. This study explains the classification, nutritional composition, bioactive compounds, growth-promoting effects, immunomodulatory properties, disease resistance mechanisms, and future prospects of seaweeds as functional feed additives in aquaculture.

Keywords: Seaweeds, Aquafeeds, Growth performance, Immune response, Disease resistance, Bioactive compounds.

Introduction

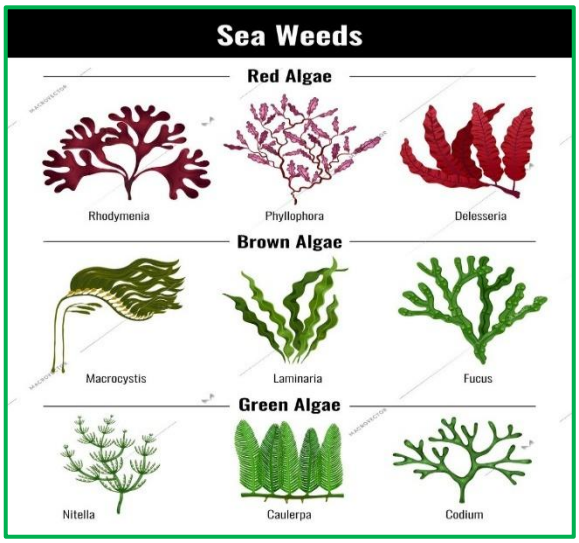
Aquaculture contributes significantly to global food production and food security. The rapid expansion of aquaculture has increased the demand for high-quality and sustainable feeds. Traditional feed ingredients such as fishmeal and fish oil are becoming increasingly expensive and environmentally unsustainable due to overexploitation of wild fish stocks. Therefore, alternative feed resources that support fish growth and health are required. Seaweeds, commonly known as marine macroalgae, have attracted considerable attention as sustainable feed ingredients in aquaculture. They are naturally abundant and contain a wide range of nutrients and bioactive compounds. Seaweeds are rich sources of Proteins, Carbohydrates, Minerals, Vitamins, Pigments, Polyphenols, and Biologically active polysaccharides. These compounds have been shown to improve growth performance, enhance immune responses, increase antioxidant capacity, and improve disease resistance in fish and shellfish.

The use of seaweeds as functional feed additives offers a promising strategy to improve aquaculture productivity while reducing dependence on conventional feed ingredients and antibiotics. This article discusses the nutritional and functional importance of seaweeds and their role in enhancing growth, immunity, and disease resistance in aquaculture species.

Classification of Seaweeds

Seaweeds are generally classified into three major groups based on pigmentation and biochemical characteristics:

- Green seaweeds (Chlorophyta)
  - ✓ *Ulva spp.*
  - ✓ *Enteromorpha spp.*
- Brown seaweeds (Phaeophyta)
  - ✓ *Sargassum spp.*
  - ✓ *Laminaria spp.*
  - ✓ *Undaria spp.*
- Red seaweeds (Rhodophyta)
  - ✓ *Gracilaria spp.*
  - ✓ *Hypnea spp.*
  - ✓ *Kappaphycus spp.*



Bioactive Compounds Present in Seaweeds

The functional properties of seaweeds are largely attributed to their bioactive compounds. Major compounds include:

- *Kappaphycus* → Carrageenan
- *Ulva spp.* → Ulvan
- *Gracilaria spp.* → Agar and Catechin
- *Gelidiella* → Quercetin and Agar
- *Sargassum spp.* → Fucoidan
- *Laminaria spp.* → Laminarin
- *Porphyra spp.* → Porphyran

These compounds exhibit antimicrobial, antiviral, antioxidant, and immunomodulatory activities. Fucoidan has been reported to possess antibacterial and antiviral properties, while laminarin and ulvan act as potent immunostimulants. Phlorotannins and phenolic compounds contribute significantly to antioxidant activity.

Seaweeds as Functional Feed Additives in Aquaculture

The use of seaweeds as feed additives has gained considerable attention due to their ability to enhance fish performance and health. Seaweeds can be incorporated into diets either as whole meals, extracts, or purified bioactive compounds. Their inclusion improves nutrient utilization, digestive efficiency, and physiological performance of cultured species.

Effects of Seaweed Supplementation on Growth Performance

Numerous studies have reported positive effects of seaweed supplementation on growth performance and feed utilization in fish. Several experimental studies have confirmed these findings. Dietary supplementation with the brown seaweed *Sargassum portieranum* significantly improved body weight, length, survival, and specific growth rate in Nile tilapia (*Oreochromis niloticus*). Fish fed diets containing 10% seaweed supplementation exhibited superior growth performance compared to fish receiving control diets. Furthermore, seaweed supplementation increased lipid and mineral content of fish muscle, thereby improving nutritional quality. Similarly, supplementation of Nile tilapia diets with red seaweeds *Hypnea cornuta* and *Hypnea musciformis* resulted in enhanced growth performance. Fish fed diets containing 20% *H. cornuta* recorded the highest weight gain and specific growth rate. Feed conversion ratio remained optimal, and survival reached 100% throughout the experimental period.

Immunomodulatory Effects of Seaweeds

Seaweed derived polysaccharide enhance macrophage activity, stimulate phagocytosis, increase lysozyme activity, and promote the production of immune-related molecules. Improved immune responses enable aquatic organisms to better withstand environmental stressors and pathogenic challenges. Seaweed supplementation has also been associated with increased expression of immune-related genes and enhanced antioxidant defense systems. Ulvan derived from green seaweeds has been reported to stimulate innate immunity and improve resistance against bacterial infections. Similarly, fucoidan obtained from brown seaweeds enhances immune responses, antioxidant activity, and disease resistance in several cultured fish species. These immunomodulatory properties make seaweeds attractive alternatives to synthetic immunostimulants used in aquaculture.

Antioxidant Properties of Seaweeds

Seaweeds contain numerous antioxidant compounds, including Phenolics, Flavonoids, Carotenoids, Vitamins, and Phlorotannins, which protect cells from oxidative damage. These compounds neutralize reactive oxygen species and improve antioxidant enzyme activities such as Super Oxide Dismutase, Catalase, and Glutathione peroxidase. Enhanced antioxidant capacity contributes to improved physiological condition, stress tolerance, and overall health of cultured fish.

Disease Resistance and Antimicrobial Activity

Seaweeds possess significant antimicrobial and immunostimulatory properties that enhance disease resistance in cultured aquatic organisms. Bioactive compounds such as fucoidan, ulvan, carrageenan, alginate, and phenolic compounds exhibit inhibitory effects against important aquaculture pathogens, including *Vibrio*, *Aeromonas*, and *Streptococcus* species. Dietary supplementation with seaweeds has been shown to improve survival, stimulate immune responses, and increase resistance to bacterial infections. For example, methanolic extracts of *Ulva fasciata* significantly improved survival and protection against *Vibrio* infection in pearlspot fishes (*Etroplus suratensis* and *E. maculatus*). These findings indicate that seaweed-derived compounds can serve as natural alternatives to antibiotics for disease management in sustainable aquaculture.

Challenges and Future Perspectives

Despite their numerous benefits, the use of seaweeds in aquaculture is limited by variations in nutritional composition, seasonal availability, and species-specific responses. High inclusion levels may also reduce feed digestibility and growth performance. Future research should focus on optimizing inclusion levels, identifying novel bioactive compounds, and developing standardized seaweed-based feed formulations. With continued advancements in aquaculture nutrition, seaweeds have strong potential to serve as sustainable functional feed additives and natural alternatives to antibiotics in aquaculture.

Conclusion

Seaweeds represent a promising and sustainable source of functional feed ingredients in aquaculture. Their rich nutritional composition and abundance of bioactive compounds contribute significantly to improved growth performance, feed utilization, immune responses, antioxidant status, and disease resistance in aquatic organisms. Numerous studies have demonstrated the beneficial effects of seaweed supplementation on fish and shellfish health, particularly when included at appropriate dietary levels. Bioactive compounds such as fucoidan, laminarin, carrageenan, alginate, ulvan, and phlorotannins play important roles in enhancing immunity and protecting aquatic animals against pathogenic infections. Furthermore, seaweeds offer an environmentally friendly alternative to conventional feed ingredients and antibiotic-based disease management strategies. Despite challenges related to variability in composition and optimal inclusion levels, seaweeds have considerable potential for future applications in sustainable aquaculture. Continued research and development will further strengthen their role in improving aquaculture productivity and aquatic animal health.

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