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Enhancing sustainable aquaculture production through Periphyton-based practices

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Abstract
Periphyton-based aquaculture represents a form of aquaculture that attaches periphyton, a diverse mix of microorganisms (including algae, bacteria, fungi, and protozoans) that adhere to submerged surfaces, as a primary food source for aquatic organisms. In this cultivation approach, aquatic organisms such as fish, shrimp, or other invertebrates are raised in systems where periphyton naturally grows or is intentionally fostered. This method is particularly well-suited for herbivorous or omnivorous species, as they can directly or indirectly consume periphyton within the food chain. Overall, periphyton-based aquaculture emerges as a promising and sustainable alternative to traditional aquaculture practices, especially beneficial for small-scale farmers in developing countries. This approach holds the potential to provide a reliable source of food and income for local communities while mitigating environmental impacts.

Keywords: Periphyton, aquaculture, fish, shrimp, sustainable

Introduction

Periphyton, also known as "attached algae," denotes a diverse community of organisms inhabiting submerged surfaces, encompassing both attached forms and those closely associated with them. This group includes a variety of life forms such as algae, zoological and filamentous bacteria, attached protozoa, bryozoans, rotifers, and even free-swimming microorganisms. Thus, the term "periphyton" not only refers to the small, sessile organisms dwelling within a slimy matrix on submerged aquatic objects but also encompasses the free-living organisms intricately linked with this matrix. The intricate nature of periphyton makes it a significant component of benthic algal communities, particularly contributing to the overall algal production in shallow aquatic ecosystems. The community's composition, comprised of various organisms with different ecological roles, highlights its importance in the intricate web of aquatic ecosystems (Singh, 2023) [12]. Despite the prevailing assumption that the phytoplankton community holds primary significance in terms of energy fixation and sustaining the aquatic food web, research indicates that macrophytes and periphyton also play pivotal roles and, in certain scenarios, emerge as the dominant contributors to primary production (Sahu *et al*., 2021) [11]. Moreover, in-depth nutrient assessments have revealed that epiphytes play a substantial role in nutrient cycling, actively consuming a significant proportion of available carbon, nitrogen, and phosphorus as they grow. Additionally, they contribute to the decomposition of macrophytes, further influencing the nutrient dynamics within the aquatic ecosystem (Abwao *et al*., 2013) [1]. They have the capability to facilitate the transfer of nutrients, such as phosphorus, from sediment abundant in nutrients to water that is comparatively nutrient-poor, using macrophytes as mediators in the nutrient cycling process. Periphyton is recognized as a significant dietary source for fish and plays a crucial role in nutrient transportation within aquatic ecosystems. In the pursuit of economical fish farming, diverse substrate-based aquatic systems have been innovated for both finfish and shellfish cultivation. These systems aim to serve as habitats while concurrently fostering the growth of periphyton as a natural food source, ultimately contributing to the enhancement of aquaculture production.

The feasibility of advancing periphyton-based fish farming technology suggests the potential for substantial steps in the progress of cost-effective aquaculture. This approach holds promise for development without the need for supplemental feed and contributes to pollution reduction (Ruby *et al*., 2018) [10].

Several types of periphyton-based aquaculture practices

Polyculture: The approach of cultivating various species of aquatic organisms in a shared system, where they utilize the same periphyton food source.

Integrated farming

The integration of aquaculture with other agricultural practices, such as agriculture, horticulture, or livestock production, to establish a closed-loop system optimizing resource utilization and minimizing waste.

Recirculatory aquaculture system

An aquaculture approach employing a closed-loop system to recycle water, nutrients, and waste, enabling the efficient cultivation of aquatic organisms with minimal environmental impact.

Various substrate options are utilized in periphyton-based aquaculture

In aquaculture, substrates encompass a diverse range of materials, including coral reefs, stones, branches from trees or shrubs, larger aquatic plants, bamboo, and even plastic. The growth of periphyton on these substrates is known to contribute to the improvement of water quality in aquaculture ponds. Five distinct materials are commonly employed as substrates which are as follows:

(i) Bamboo pipe, (ii) Plastic sheet, (iii) Polyvinylchloride (PVC) pipe, (iv) Fibrous scrubber, (v) Ceramic tile.

Table 1: Various substrate used in periphyton based aquaculture system

Fish species	Substrate	References
Labeo rohita, Catla catla	Bamboo poles	Azim *et al*., (2001b) [3]
Nile tilapia	Periphyton-based feed	David *et al*., (2022a) [6]
Labeo fimbriatus	Sugarcane bagasse	Barlaya *et al*., (2021) [11]
Litopenaeus vannamei	Artificial substrate	Kring *et al*., (2023) [7]

Installation of the substrate and preparation of the pond

Prior to installation, the ponds underwent a renovation process involving the removal of aquatic vegetation and the elimination of all small fish and other larger aquatic organisms. Establishing a substrate-free perimeter, a beneficial pond zone measuring 8×3×5 m² was cultivated with bamboo sticks (mean length = 2 m; mean diameter = 5.5 cm). These bamboo sticks were inserted vertically into the pond bottom, with the upper portion extending above the water surface, achieving a density of 9 poles per square meter (Singh, 2023) [12]. The bamboo substrates offered an efficient surface area of approximately 75 m² per pond, closely matching the water surface area of the ponds. Subsequently, the ponds were filled with water, and fertilizers were applied according to the experimental design on day 1, with subsequent applications performed fortnightly (Azim *et al*., 2001a) [2].

Fig 1: Periphyton based aquaculture system

Development of periphyton assemblage

The initiation of a periphyton layer on a pristine surface typically commences with the electrostatic deposition of a coating of dissolved organic substances, primarily mucopolysaccharides. This coating attracts bacteria through hydrophobic reactions (Cowling *et al*., 2000) [5]. Throughout the formation of the periphyton layer, conditions for the growth of various algal species undergo significant changes. With the escalating density of microorganisms, heightened competition for substrate surface area ensues, impacting the composition of the periphyton population. Additionally, organisms engage in competition for essential resources such as carbon dioxide, nutrients, and light (Singh, 2023) [12].

Role of periphyton in aquaculture system

Periphyton represents a complex amalgamation of both autotrophic and heterotrophic organisms, defying classification merely as an attached counterpart to phytoplankton. Despite its parallel functions in ponds, such as oxygen production and the absorption of inorganic nutrients, periphyton transcends a simplistic equivalence to phytoplankton. A substantial exchange of both inorganic and organic nutrients occurs within the autotrophic and heterotrophic components of the periphyton assemblage. This exchange potentially leads to a reduced accumulation of periphyton-origin detritus on the pond bottom compared to a system dominated by phytoplankton. Furthermore, the periphyton layer traps and processes suspended organic substances. In a periphyton-based system, the biomass developed is retained in the aerobic zones of the pond, facilitating rapid decomposition and making it readily accessible for grazing by fish.

Role of periphyton in the aquatic food web

The significance of periphyton as a vital group of organismal aggregations has led to the establishment of a harmonious relationship between periphyton and other elements within aquatic ecosystems. Periphyton can play a substantial role in primary productivity, especially in shallow freshwater ecosystems, thereby offering a crucial energy input to the detritus and grazing food chains within the ecosystem (Liboriussen and Jeppesen, 2003) [8]. In extensive and semi-intensive ponds, two fundamental food sources sustain all organisms: the primary productivity derived from algae and the introduction of organic substances as supplementary feed. In the first scenario, algae produce organic substances through photosynthesis, utilizing solar energy and carbon dioxide. These substances are then utilized indirectly by secondary trophic levels (zooplankton, benthos, and invertebrates) and/or directly through fish grazing. In the second scenario, the addition of organic matter as supplemental feed serves to enhance fish production. Periphyton aquaculture proves to be advantageous for Indian fish farming. The incorporation of periphyton substrates, coupled with the economical addition of carbohydrates, has demonstrated improvements in the production performance and water quality of both finfish and shrimp aquaculture (Xu *et al*., 2016) [13]. Periphyton communities-initiated growth on the substrate, contributing to enhanced water quality through various mechanisms, including the trapping of suspended solids, improvement in nitrification, and breakdown of organic materials. Additionally, an improvement in growth performance has been reported as periphyton serves both as a food source and a shelter (Pandey *et al*., 2022) [9].

Different advantages of periphyton based aquaculture system: Periphyton-based aquaculture demands minimal energy inputs and can be implemented with low-cost materials. This cost-effectiveness allows farmers to produce fish or other aquatic organisms at a reduced expense, thereby enhancing their profit margins. Periphyton-based aquaculture enables farmers to diversify their income streams by cultivating multiple species of fish or other aquatic organisms within the same system. This diversification helps spread risk and establishes a more stable source of income. Periphyton-based aquaculture holds the potential to enhance productivity by offering a natural and sustainable food source for fish or other aquatic organisms. This can lead to accelerate growth rates and increased yields, ultimately translating into higher profits. Utilizing periphyton as a food source enables farmers to diminish their dependence on costly and environmentally harmful inputs. This practice contributes to enhancing the health of the surrounding ecosystem and lessening the overall environmental footprint.

Conclusion

In essence, periphyton-based aquaculture holds the potential to offer farmers a sustainable source of income while mitigating environmental impacts. Embracing this approach may enable farmers to enhance productivity, lower operating costs, and diversify income streams, thereby paving the way for potential income doubling over time. Nevertheless, it is crucial to emphasize that the success of periphyton-based aquaculture necessitates meticulous management and continuous monitoring of water quality and nutrient inputs. This is essential to sustain healthy periphyton growth and prevent potential adverse impacts on the ecosystem.

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