**SUBSTRATE BASED AQUACULTURE**

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**Aquaculture**

Aquaculture contributes significantly to global food security and protein supply and supports many livelihoods. It is the fastest growing sector of animal production, more than 50 percent of seafood produced for human consumption comes from fisheries. However, the intensification of aquaculture has led to the increasing use of various drugs and chemicals that are harmful to aquatic ecosystems. The current trend in aquaculture development is the increasing intensification and commercialization of aquaculture. Aquaculture is not only considered an important initiator of development, but also an important tool to increase food security. Rural aquaculture, including enhanced fisheries and culture-based fisheries, has contributed significantly to poverty alleviation. This was done directly by small farmers who cultivate aquatic organisms for domestic consumption and income generation. Indirectly, this was done by providing labor and supplying cheap fish to local markets. There are many opportunities for the poor to integrate aquaculture into their existing agricultural systems, and thus there is still room for growth in aquaculture production, most of which must be realized through the efforts of the poor.

**Heterotrophs in Aquaculture**

Autotrophs, heterotrophs and detritus are typical natural nutrients for fish in aquatic ecosystems. Aquatic macrophytes, periphyton and phytoplankton are the main components of autotrophic food. These autotrophic and heterotrophic microorganisms are the two main functional units of the microbial food web due to their central role in nutrient cycling and carbon flow in the water column. However, because aquatic macrophytes compete with algae for nutrients, they are less important in fertilized ponds. The main constituents of heterotrophic food are bacteria, protozoa, fungi, zooplankton and benthic animals (micro- and macro-invertebrates). Most of the litter consists of living organic fragments of dead autotrophic and heterotrophic organisms.

Fish in aquaculture systems can be fed by three different feeding processes: direct feeding with feed produced by the fish; autotrophic feeding, where primary producers use solar energy to convert carbon dioxide into organic matter that fish can use; and heterotrophic nutrition, in which heterotrophic organisms break down organic matter that can be used by fish (Schroeder, 1978). The flow of organic and inorganic nutrients largely depends on the connection between these three pathways. Most extensive and semi-intensive ponds have two main sources of food for all organisms: (1) primary algal productivity and (2) organic matter added as feed or fertilizer. Secondary trophic level feeders (zooplankton, benthic organisms, invertebrates, etc.), including fish, use organic matter produced by algae through photosynthesis. In the latter case, organic matter used as supplementary feed or fertilizer increases primary productivity and fish production through direct or indirect consumption of fish. In both cases, heterotrophic microorganisms are important parts of the food web because they break down organic matter and release nutrients that can be used by algae or consumed by fish. In most cases, heterotrophic food production is greatly influenced by the nature of the organic matter, bacteria, and environmental variables such as dissolved oxygen, temperature, etc. Because it is light-independent and able to supply the necessary chemicals as well as the organic compounds that act as an energy source, the entire water column can be heterotrophically productive. By spreading fertilizer in divided doses at frequent intervals instead of a single dose, the production of heterotrophic food can be increased. Thus, using periphyton technology, the production of heterotrophic food in the pond can be encouraged even at night.

**Periphyton Based Aquaculture**

Periphyton is a general term for microorganisms that thrive in any underwater substrate, consisting of algae, bacteria, fungi, aquatic invertebrates, protozoa, and debris. In microbiology, periphyton are often referred to as "biofilms" (Shankar and Mohan, 2001). Van Dam et al. (2002) explain that the assemblage of attached organisms on an underwater surface, including associated non-attached fauna, is called the periphyton. While both autotrophic and heterotrophic pond food webs are traditionally influenced by phytoplankton, which is an important part of natural food production, periphyton, on the other hand, serves the same purpose as phytoplankton and is more stable, making it more beneficial to many fish. who lives at the bottom of the food chain. The periphyton community consists of bacteria, fungi, protozoa, phytoplankton, zooplankton, benthic animals and many different invertebrates and their larvae. This microbial mat develops naturally on underwater surfaces in the presence of light and nutrients. The diverse microbiota of the periphyton (primary photoautotrophs) have different metabolisms for nutrient utilization (Anand, 2013). The interaction of all these microorganisms, including phytoplankton, results in a natural food source for farmed fish or crustaceans. In addition, periphyton bacteria have various naturally occurring bioactive substances that can increase the resistance of fish to stressful situations such as overcrowding. Periphyton can also act as a probiotic or vaccine, as well as an antibiotic against several contaminating bacteria. The idea of ​​periphyton-based aquaculture originally originated from a traditional method (testing bush traps) locally known as "paddle fishing", a unique fishing method used in the Ashtamudi Delta, Vambanad, Kerala (South India). Here, branches of locally available trees such as mango, mangrove and bamboo poles are placed in the shallow open water. These branches are known as podals, which act as a link between the shrimp and the fish.

**Indigenous periphyton Aquaculture Practices**

**Acadja**

In a West African coastal lagoon, a dense group of branches artificially planted on the muddy bottom of shallow water (1-1.5 m deep). About 1 package/m2 of bundles and piles is applied in these lagoons. Such acades are kept without fish for 6 months to 1 year. After this period, these components attract fish and collect them. Acadja yield is known to be 4-20 tons of fish/ha/year. Algal dry matter (DM) content increased fivefold and chlorophyll eightfold in acadjas, the researchers reported, multiplying the number of periphytic species on growth branches compared to lagoon water.

**Samarahs**

In Cambodia, floating waterweed (Eichhornia crassipes) is used along with the branches and shoots. Sixty days after substrate application, fish were collected. Andquot;Samarahsandquot produced approximately 4 tons/ha/year of fish; every season. In addition, Cambodian farmers use palm fronds and paddy straw to remove turbidity from water, which also increases productivity by acting as a substrate for periphyton growth.

**Katha**

In rivers and canals trees like mango, Barringoronia sp., Eugenia sp., Acacia sp. etc., the branches of the bushes act as a natural substrate for algae to attach to. This is a traditional fishing method where branches are attached to bamboo bones, which also act as a driving force in the colonization of algae populations. Katha can increase biological production in three different ways: 1) by creating safer and more diverse spawning grounds for some species, thereby increasing reproductive success; 2) reducing the number of predators and increasing the survival of young and offspring; and 3) creation of large food reserves through the cultivation of periphyton, a high-quality natural food, thereby increasing fish growth and fitness. An analysis of the Katha fishery showed that fish production increased by about 33 percent.

**Phum**

Submerged aquaculture methods are commonly used in the Lok Tak Lake in the state of Manipur, India, which is located in the northeastern part of the country. The lake is covered with floating islands that act as natural aggregation structures for fish. These islands are formed by a dense growth of water-rich weeds and grasses. These floating islands are made by bending the cut leaves of the grass mats into circles after cutting them to a width of 1-2 meters. Bamboo and ropes are used to secure the two ends. After the circle is completed, it is dragged to a designated spot in the lake where it is secured with bamboo. Trees are harvested every one to two months. The production of these dust areas is said to be about 300-1000 kg per smoke.

**Xeng fishery**

In Assam of north-east India, bamboo branches (locally called Xeng), especially from *Bambusa balcooa*, *B. pullida*, *B. arundinecia*, etc. are irregularly implemented for home grown fish ponds. Such Xeng fishery can produce at least 25% more fish production than conventional Xeng free ponds.

**Roles of Periphyton**

**Food source and nutrition**

Periphyton is an important food source for many fish in both wild and cultured ponds. According to several studies, periphyton can be used as a natural feed source for caged tilapia, which would significantly reduce the need for supplemental feeding and increase profitability. Additionally, farmed fish can graze quite well on attached periphyton compared to scavenging small planktonic algae from the water column. Compared to phytoplankton, periphyton algae are more stable and produce more per unit water surface. Compared to filtering algae from a three-dimensional planktonic environment, periphyton are better suited for grazers and scavengers due to their two-dimensional structure. Periphyton can provide up to 75% of metabolic energy to fish when used as feed in aquaculture, helping to increase fish productivity. Indian large carp, tilapia, common carp and shrimp prefer periphyte as natural food. Many fish and benthic invertebrates, including snails, chironomids, butterflies, oligochaetes, and several groups of crustaceans, include periphyte in their diet. Periphyton growing on the substrate in freshwater ponds can be one of these additional sources of nutrients. Periphyton algae not only act as a food source, but also help improve the nutritional value of cultured species.

**Water quality**

More nutrients are transferred to higher trophic levels in periphyton-based systems rather than accumulating in the system rather than in feed-operated ponds. They have been used in aquaculture to improve species production and water quality. Periphyton-based systems also have greater nitrogen retention at higher trophic levels that can be used by fish species. As a result, these systems have the ability to improve nutrient efficiency, which reduces waste accumulation and improves overall water quality. In aquaculture systems, biofilm formation on substrates can act as an in situ biofilter and filter; reduces the amount of toxic ammonia. The environmental temperature of the natural substrate shows the opposite tendency with the vegetation growth. The transparency of a water body usually indicates its productivity, while; there was always an inverse relationship between periphyton growth and water clarity, which is mostly due to leaching of the natural substrate. Periphyton can bind organic waste, remove nutrients from the water column and help regulate the dissolved oxygen concentration and pH of the surrounding water. In traditional aquaculture ponds, nitrification occurs primarily at the sediment surface and is limited by both surface area and oxygen availability. In addition, the area required for slow-growing chemoautotrophic nitrifying bacteria may be limited by fast-growing heterotrophic bacteria. Therefore, periphyton microorganisms increase nitrification, keeping ammonia levels low. Water purification is facilitated by periphyton and #039 nutrient recycling, as some algae can consume ammonia and help remove phosphates from the water column. Bacteria attached to the substrates undergo nitrification, the final product of which is nitrate-N, which promotes an increase in the number of autotrophs in the water column, leading to a decrease in ammonia-N and nitrite-N in the substrate-based treatments compared to others treatment. In addition, the biofilm formed on the substrates increases the assimilation of nitrogen molecules, generating large amounts of dissolved oxygen. Several studies have shown that periphyton has a positive effect on nitrification, resulting in a reduction of ammonia concentrations. Similarly, phytoplankton and periphyton used available nitrate and phosphate mixtures on the substrate for green growth, reducing their levels in the water segment.

**Productivity and Nutrient Transfer**

Periphyton compounds have several functions that contribute to nutrient retention. They can first remove nutrients from the water column and lead to a net flow of nutrients towards the sediments. Thanks to this, less phosphates will be transported from the sediments in the future. Second, they can slow water exchange across the sediment or water column boundary. Third, they can prevent the spread of aging macrophytes or nutrients from bottom sediments. Finally, they are able to trap particles in the water column. They can also provide biochemical conditions that favor phosphate deposition. Periphyton-based systems have shown higher nutrient use efficiency compared to traditional substrate-free systems, so it is assumed that the optimal fertilization of traditional substrate-free ponds is sufficient to maximize fish production in periphyton-based systems. Periphyton act as a nutrient store and remover in water bodies, being able to actively regulate the transport and transformation of nutrients between the water and soil/sediment interface.

In periphyton based ponds, competition and interactions between periphyton and phytoplankton interfere with the link between phytoplankton productivity and nutrient concentrations, which can be positive in ponds and lakes. Greater grazer biomass results from increased nutrient levels, which shows that nutrients are effectively transferred to higher trophic levels. Low nutrient concentrations limit periphyton biomass, but when nutrient supply increases, competition for light, both within the periphyton and with other primary producers, becomes more important.

**Economics of Periphyton based technology**

Periphyton based aquaculture has an advantage of being economically sustainable hence can easily be adopted by poorer fish farmers. Installation of low-cost substrates in the culture system performs better than the traditional non-fed or fed systems, in both ecological and economic points of view. Various studies have shown how this technology is comparatively low in terms of cost of production while the returns are much higher than systems that do not use periphyton based technology. In semi-intensive culture systems, installation of artificial substrate increases the economic return. In a study by Huda and his team, evaluated the relative profitability of periphyton based aquaculture both on-station and on farm situation. The findings of the study showed relatively lower production cost compared to that of existing fish production practice (supplementary feeding). Jha *et al.* (2018) concluded reduced feed application with increased periphyton enhancement dramatically improved profit when maintaining fish yields similar to those of traditional polyculture systems with full feeding in farming of carp polyculture in Nepal. Hoque *et al.* (2018) proved that regulating periphyton growth on bamboo poles to increase fish production will be economically profitable and it helps to minimized considerably production cost. Keshavanath *et al.* (2012) revealed that use of cheap biodegradable substrates for the growth of periphyton can greatly improve economic viability of carp aquaculture.

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