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# Biofloc technology: An innovative approach to zero-water exchange and tentative zero-feed system: A review

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**Abstract**
The intensification of aquaculture since last decade increased at a greater pace to increase per unit production. Likewise, several techniques have been developed over the years while leaving a scope of improvement either inefficiency or production-wise. Limited available resources *viz.* Land and water, increasing feed cost, diseases and waste management are a serious problem in the current scenario of aquaculture. The developed waste due to vivid inputs (feed, fertilizers, etc.) contains a high concentration of metabolites, fecal matter and unutilized feed, which leads to water quality deterioration. Biofloc technology is proven as zero water exchange and cut down the feed cost-efficiently. Therefore, biofloc can be considered as, sustainable, environment-friendly and cost-effective technology which can be used to develop a zero water exchange culture system to avoid the problem of waste generation and discharge. In this techniques, maintenance of high levels of microbial floc in suspension using constant aeration and addition of carbohydrates to allow aerobic decomposition of the organic material, which stimulates the growth of heterotrophic bacteria and uptake nitrogen from water and in turn produces microbial proteins which are utilized as food sources by fish or shrimp. BFT is having several advantages over the traditional culture system. It is robust, easy to operate, more profitable and economically feasible.

**Keywords:** Biofloc technology, sustainable, aquaculture

## Introduction

The estimated global aquaculture production is around 171 million tons in 2016 [20]. World per capita fish supply reached a new record high of 20.3 kg in 2016. World population is growing rapidly and by 2050 it is expected to cross 9 billion and hence food production has to be doubled to fulfil the demand. Supply of nutritionally balanced and high-quality protein food to growing population is a major challenge of the front of in the world. Malnutrition is a serious problem throughout the world. Today around 840 million people are suffering from malnutrition [44]**.**

Aquaculture is considered the fastest-growing food production sector in the world. It has the potential ever-increasing population to feed them. The aquaculture production system has undergone major culture fisheries than capture fisheries. Aquaculture remains the most important source of food, nutrition, income and livelihoods for millions of people in the world. Aquaculture has changed today from extensive to the intensive system. The feed is the major costs above 50 % of total production cost. Aquaculture farms are generating an organic load and access of nutrient to the natural environment and ultimately got a result spreading of disease from one to another farm. Therefore, avoid this serious issue by developing a zero water exchange system. This organic load has rich of ammonia and other access to nutrients. It is toxic for fish and shrimp. It is retarded survival, growth, oxygen consumption and causes high mortality. Ammonia in water exists in two forms unionized ammonia and ionized ammonium. Among this unionized ammonia is more toxic [8]**.** The common method for dealing with this problem is the continuous exchange of pond water with external freshwater, and the second method to decrease major pollutants in the water is by adopting a recirculatory aquaculture system (RAS) with different types of water treatment systems [21]. The advantage of close aquaculture systems is greater control over the water quality, more production per unit area and disease management [4, 30]. But the RAS technology is very expensive. Therefore, there is an alternative approach to control the water quality, reduce the toxic level and tentative feed within a one culture system to avoid the problem of waste discharge. It is nothing but Biofloc technology. Biofloc technology is sustainable, environment-friendly and cost-effective technology and can be used to develop a zero water exchange culture system.

**What is Biofloc?**

Biofloc is an assemblage of beneficial microorganisms such as heterotrophic bacteria, algae (dinoflagellates and diatoms), fungi, ciliates, flagellates, rotifers, nematodes, metazoans & detritus [32]. Macro aggregates composed of bacteria, algae, protozoa, rotifers, copepods, feces, exoskeleton, and remains of dead organisms, nematodes, macro-algae, various invertebrates and other microorganisms. A bio floc consists of a heterogeneous mixture of microorganisms, particles, colloids, organic polymers, cations and dead cells and can reach more than 1000 pm in size.

**Biofloc technology**

Biofloc technology is an innovative approach with the ability to solve problems of nitrogen-based toxic compounds. The technology is based upon zero water exchange, enhances biosecurity and minimizing problems caused due to the exchange of water to both the environment and culture system. BFT is reducing investment, maintenance costs and recycle feed and other nutrients. Biofloc technology is an aquaculture system where heterotrophic bacteria and algae are grown in floc under control conditions within the culture system. These microbial biomasses grow on unconsumed feed, fish excreta and inorganic nitrogenous products resulting in the removal of unwanted components from the water. Biofloc technology is based on maintenance of a high level of microbial flocs in suspension by using constant aeration to allow aerobic decomposition [7], as well as on the principle of flocculation within the system. Such condition facilitates the development of dense microorganisms which functions as a bioreactor and maintains water quality and in turn utilized by fish as a protein source [15], Further addition of carbohydrate stimulates the growth of heterotrophic bacteria which consume organic carbon [1,40] and which uptake nitrogen from water and in turn produces microbial proteins [6, 5, 1]. The biofloc technology makes it possible to minimize water exchange and maintaining water quality within the culture unit while producing low-cost biofloc rich in protein, which in turn can serve as a portion of food for aquatic organisms [12, 15, 11]. The immobilization of toxic nitrogen species occurs much more rapidly in biofloc because the growth rate and microbial biomass production per unit substrate of heterotrophs are 10 times higher than those of autotrophic nitrifying bacteria. Microbial communities' grow in the culture pond by providing vigorous aeration and proper carbon: nitrogen ratio. Artificial aeration is used to supply vigorous oxygen to the community and also to suspend organic particles which are prerequisite for biofloc development. This microbial community role in minimizing wastes, improve protein utilization and reduce pathogenic strains [23].

The biofloc has been reported many positive effects on improvement of water quality parameter, supplementary source of protein, improvement of disease resistance, biosecurity and better health management practices through zero-water exchange and possible probiotic effect [47].

**History of biofloc technology**

Algae detritus is the main organic substances for bacterial growth and live algae provided oxygen to decomposition in culture pond [10] and algae are regenerating inorganic nutrient and vitamin for further growth of algal productivity. Flocculation of algae and clay together and the addition of fertilizer induced the algal growth [2]. Addition of vigorous aeration and mixing of water in the pond it is minimizing the accumulation of toxic material the ammonia in water [3]. Biofloc technology was first tested in aquaculture pond with autotrophic and heterotrophic microorganism interacting algae and bacteria gave result complex water dynamic [1,10]. Autotrophic and heterotrophic bacteria converted complex to the simple non-toxic compound. Biofloc technology is proved benefits for both shrimp and finfish [30]. Biofloc technlogy is the popular culture of tilapia, giant freshwater prawn, tiger shrimp, and white leg shrimp. Biofloc technology has been successfully applied to shrimp farming in Indonesia and Australia [42].

**Type of biofloc system**

There are mainly a few types of biofloc system research and commercial purpose used in the aquaculture production system. The systems are on them based on the presence of light. Those that are exposed to natural sunlight outdoor biofloc tank/pond and those that not exposed light indoor biofloc tank/pond [22, 34]. In this outdoor bio floc, culture system presents of algae and bacteria both complex combinations help to control water quality parameter and presents of light greenish colouration of water due to green algal growth that's a system called green biofloc system. Phytoplankton can control water quality by uptake the toxic substances like ammonia and nitrite products. Here phytoplankton is produced oxygen after the photosynthesis so this fully enriched system [22]. Indoor biofloc culture system only presents of bacteria help to control water quality parameter and presents of brownish colouration of water due to bacterial growth that's a system called brown biofloc system [34]. In the Indore biofloc system ammonia concentration is controlled by the help of bacteria to improved water quality parameter by maintaining C/N ratio is rice by adding organic carbon sources or reduced protein in fish feed. It means amount produce ammonia in the pond which is consumed by bacteria as nitrogen sources and carbon is consumed through water as energy sources through concentration of ammonia can controlled by addition of carbon sources. There are three type of biofloc green, black and brown colouration of biofloc system observed the culture of shellfish, finfish and shrimp but the better growth gets in the shrimp. The addition of high molasses as carbon sources in green water biofloc system protected again the WSSV in shrimp [29]. An addition of molasses reduced concentration of nitrogenous waste in culture pond [43].

**Significance of C: N ratio in biofloc technology**

In the biofloc technology Carbon: nitrogen ratio main role plays in Biofloc development. Biofloc based aquaculture is an alternative approach for the sustainable development of aquaculture and this technology is based on the concept of carbon-nitrogen (C/N) ratio [1, 6, 12]. The control of inorganic nitrogen accumulation in the pond is based upon carbon metabolism and nitrogen immobilization into microbial cells. The relationship of carbon source, reduction of ammonia and production of microbial proteins depend on the microbial conversion coefficient (C/N ratio) [1]. He also revealed that the addition of carbon source was effective in reducing toxic nitrogen in shrimp and tilapia fish culture. The reduction of toxic nitrogenous species from the intensive vigorous aerated ponds by the application of organic carbon sources by maintaining of C/N ratio in the pond. This method has facilities to reuse water, minimize exchange, and eliminate discharge. This will improve the outlook for more profitable and sustainable production technologies [9]**.** When the C/N ratio of the organic matter is higher than 10, immobilization of nitrogen takes place [26]**.** The addition of suitable carbohydrate sources is a potential method for controlling the inorganic nitrogen species in the culture of *P. monodon* in biofloc systems [45]**.** Maintain the C/N ratio in the aquaculture system, through the external addition of carbon source water quality can be improved along with the production of high-quality single-cell microbial organisms [14]**.** The effects of C/N ratios with increasing C/N ratio from 10 to 20 reduced the total ammonia nitrogen nitrite nitrogen and nitrate nitrogen in the water column and total nitrogen in the sediment [27]**.** He further concluded that for highest growth, survival, production and net benefits, C/N ratio of 20 and a stocking density of 25 fish $m^{-2}$ are optimal. The lower level of nitrogen compounds occurred in the C: N ratio of 10:1 and it provides a higher growth rate and survival tilapia without water exchange.

**Biofloc development using different carbon sources**

Different organic carbon sources (glucose, cassava, molasses, wheat, corn, sugar bagasse, sorghum meal, etc.) are used to enhance production and to improve the nutrient dynamics through altered C/N ratio in shrimp culture [1]**.** The nutritional properties of bio flocs are mainly depend on the types of carbon source used to produce the flocs [11, 13]**.** Simple sugars, such as sucrose, result in a faster ammonia removal, while more complex carbohydrates require more time for decomposition into simple sugars, thereby resulting in slower ammonia removal [18]**.** Overall, bioflocs produced on glycerol gave the best results [11]**.** The addition of carbohydrate significantly reduced the total ammonia-N (TAN), nitrite-N and nitrate-N in water and it significantly increases the total heterotrophic bacteria (THB) population in the biofloc treatments and growth of *Litopenaeus vannamei* was higher in the wheat flour treatment [36]**.** The corn-based biofloc treatment group showed improved FCR and SGR and higher weight gain [46]**.**

**Advantages of biofloc in aquaculture**

There are major advantages of sustainable biofloc technology. The main advantages is the culture aquatic animal fish, shrimp and growth of microorganism in same medium benefit of minimum or zero water exchange from culture. To maintain the water quality parameter and produce protein-rich feed for fish by microorganism from the utilization of nitrogen from waste. Farmer is following biofloc because it's utilized less commercial feed and got good food conversation ratio and better protein utilization. In this system higher growth of fish and maintain all sustainability like ecological, biological and environmental sustainability [12, 19]. Besides, it has less use of land, lesser impact on the environment and utilization of nutrient within the culture. This technology cultured at higher stocking rate, improved digestive enzymes with improved growth, less disease chances [17]. Increase the higher level of amylase and lipase with improves growth and survival in white leg shrimp when it was cultured under microbial biofloc culture. The biofloc system used for multiple productions cycle with harmful impact production yield utilized waste nitrogen and maintain optimum water quality parameter [24]**.** BFT lowers the feed conversion rate by utilizing the in situ natural feed and has small footprints; hence reducing environmental impacts [15] zero water exchange bio floc system also maintains temperature with heat fluctuation. It is robust, easy to operate and economically flexible for the farmer. Harvested waste material is high protein-rich content which is utilized as feed by shrimp and fish. Advantages of the technology in aquaculture has been well documented which includes low feed and water input, less risk of pathogen introduction and diseases, more biosecurity, increased growth and survival, and hence increased crop yield [15, 31, 33]**.**

**The drawback of biofloc system**

There are so many limitations of biofloc system. In this technology higher level of managerial skill and monitoring required. Involved more technicality and understanding of the system higher set-up cost is a major problem for biofloc system. Start-up time period required. To sustain the biofloc, high stocking density-biomass of shrimp is required. There is required higher aeration during culture for mixing of flocs. Therefore Power back generator is a requirement. Oxygen is very critical, aeration and energy cost increases Pond plastic lining is recommended.

**Biofloc technology in Aquaculture**

Biofloc technology (BFT) has been successfully implemented in aquaculture especially shrimp farming due to economic and environmental advantages over a conventional culture system. It has been widely used for reducing the accumulation of ammonia by its conversion into heterotrophic bacterial biomass.

The optimized the addition of carbohydrate source for the process of bio flocculation and standardize the quantity of carbohydrate source required for bio flocculation in aquaculture systems [1, 4]**.** 10–20% potential feed gain as estimated by application of biofloc technology [12]**.** The effectiveness of biofloc technology the quantity of carbohydrate addition has been optimized for the larval rearing of the giant freshwater prawn [25, 38, 39]**.**

The advantages of the technology in aquaculture has been well documented which includes low feed and water input, less risk of pathogen introduction and diseases, more biosecurity, increased growth and survival, and hence increased crop yield [15, 24, 31, 33, 37]**.** BFT is robust, easy to operate, and economically feasible [14]**.**

Biofloc technology is suited only for those species of fish which can tolerate higher density and higher amount of suspended solids. *Labeo rohita* can be a very good candidate species for biofloc based aquaculture system [35]**.** The growth of *Labeo rohita* is higher when fed with a mixture of 50% feed and 50% Biofloc. Three species of tilapia (*Oreochromis mossambicus*, *Oreochromis andersonii*, and *O. niloticus)*, *Oreochromis niloticus* showed a significantly higher growth rate and appears to be the most adequate species for use in BFT among tilapia [16]**.**

**Challenges for future research**

- Determination of the impact of carbon sources type on biofloc characteristics.
- Development of monitoring techniques for floc characteristics and floc composition.

- Optimization of nutritional quality (amino acid composition, fatty acid composition, vitamin content)
- Identification of micro-organisms yielding biofloc with beneficial characteristics to be used as inoculum for biofloc systems.
- Selection & positioning of aerators
- Integration in existing systems (such as polyculture and raceway culture system)

## Conclusion
Although researches of biofloc systems have been underway since the early 1990s and commercial application have been in place since early2000s, But some key issues of biofloc system function are still poorly understood. one of the major risk factors of these technologies is the periodic increment of total suspended solids, cause clogging in shrimp and fish gills and demands more energy to meet the oxygen demand. Promotion program must be conducted to promote awareness. This ecofriendly, stable (in terms of water quality), in-situ nutrients giving and recycling, cost-effective technology need future research for knowing the complicated things behind it.

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