REVOLUTIONIZING URBAN SOCIETY: FULFILLMENT OF ANIMAL AND VEGETABLE FOOD THROUGH BIOFLOC TECHNOLOGY AS AN INDEPENDENT FOOD SOURCE IN FAMILIES

REVOLUSI MASYARAKAT PERKOTAAN: PEMENUHAN PANGAN HEWAN DAN NABATI MELALUI TEKNOLOGI BIOFLOC SEBAGAI SUMBER PANGAN MANDIRI DALAM KELUARGA

Ariyanti Hartari*[1], Anang Suhardianto[1]

[1]Program Studi Teknologi Pangan, Fakultas Sains dan Teknologi, Universitas Terbuka

*ariyanti@ecampus.ut.ac.id

ABSTRAK

An expanding global population necessitates stable food availability, yet agriculture suffers from the consequences of climate change water and energy scarcity. Intensive food production techniques like aquaculture and greenhouse vegetable growth can be highly productive and negatively impact the environment. This system is more environmentally friendly due to various initiatives and significant scientific advancements. Wastewater is water recycled from domestic, commercial, or industrial sources. The use of biofloc technology in the aquaculture industry has gained significant acceptance among aquaculture farmers. This achievement is because biofloc technology is a cultivation approach that leverages microbial group growth in water as a source of nourishment for cultivating organisms. This system has several advantages, making it an attractive alternative for meeting sustainable food needs and *increasing resource efficiency. This paper aims to demonstrate how employing biofloc technology as a type of home (family) size urban farming. The technology is to overcome the challenge of urban society's limited land to provide food independently by combining fish and vegetable production with the biofloc system. The continuity of micronutrients in biofloc ponds for the growth of plants and fish in ponds aligns with environmental sustainability and food security principles.*

Kata Kunci: *biofloc, food production, hydroponic, aquaponic, urban community*

ABSTRACT

Peningkatan populasi global membutuhkan ketersediaan pangan yang stabil, namun bidang pertanian mengalami ancaman kelangkaan air dan energi akibat perubahan iklim. Teknik produksi pangan intensif seperti budidaya perairan dan penanaman sayuran di rumah kaca sangat meningkat produksinya dan memiliki dampak negatif terhadap lingkungan. Sistem ini lebih ramah lingkungan sebagai hasil dari berbagai penelitian dan perkembangan ilmiah yang pesat. Air limbah adalah air yang telah didaur ulang dari sumber domestik, komersial, atau industri. Penggunaan teknologi bioflok dalam industri perikanan telah menjamur di kalangan pembudidaya perikanan karena teknologi bioflok merupakan pendekatan budidaya yang memanfaatkan pertumbuhan kelompok mikroba dalam air sebagai sumber nutrisi bagi organisme yang dibudidayakan. Sistem ini memiliki beberapa alternatif keunggulan yang menarik untuk memenuhi kebutuhan pangan berkelanjutan dan meningkatkan efisiensi sumber daya. Tujuan studi ini adalah untuk menunjukkan bagaimana teknologi bioflok dapat digunakan pada lingkungan perkotaan skala rumah tangga. Teknologi tersebut diperkirakan dapat mengatasi tantangan keterbatasan lahan masyarakat perkotaan untuk menyediakan pangan secara mandiri dengan menggabungkan *produksi ikan dan sayuran dengan sistem bioflok. Keberlangsungan mikronutrien kolam bioflok untuk pertumbuhan tanaman dan ikan di kolam sejalan dengan prinsip kelestarian lingkungan dan ketahanan pangan.*

Keywords: *bioflok, produksi pangan, hidroponik, akuaponik, masyarakat perkotaan*

INTRODUCTION

An expanding global population necessitates stable food availability, yet agriculture suffers from the consequences of climate change water and energy scarcity. The agricultural industry is also responsible for worldwide freshwater resource depletion and greenhouse gas emissions, mainly CH_4 and N_2O. While intensive food production techniques like aquaculture and greenhouse vegetable growth can be highly productive, they significantly negatively impact the environment. However, this system is more environmentally friendly due to various initiatives and significant scientific advancements, such as sustainable intensification, which refers to creating sustainable food production systems with low resource requirements and high biomass output.

Wastewater is water recycled from domestic, commercial, or industrial sources. Water is 99.9% of wastewater, with the remaining 0.1% of dissolved, colloidal, and suspended particles. The technique of wastewater reuse in aquaculture has a long history in East, South, and Southeast Asia, where the world's most fabulous aquaculture production occurs. Even though conventional fish farming methods use wastewater from multiple sources without prior treatment, recent advances in engineered wastewater treatment systems include an aquaculture component in the form of maturation ponds in effluent stabilization pond systems for aquaculture.

The use of biofloc technology in the aquaculture industry has gained significant acceptance among aquaculture farmers. Because of this, the Ministry of Maritime Affairs and Fisheries of Indonesia, through the Directorate General of Aquaculture, encourages the public to implement technological innovations in the biofloc fish farming system (Fitriani, 2021). Several factors have contributed to the increasing popularity and acceptance of this technology. Following are the reasons why biofloc technology is well received:

1. Improving the quality of aquaculture water: Adharani, Soewardi, Syakti, & Hariyadi (2016) concluded in their study that the use of biofloc can improve water quality, as evidenced by a drop in the concentration values of total ammonia nitrogen (TAN), ammonia, nitrite, and nitrate parameters. In this situation, biofloc functions as a biocatalyst, efficiently converting organic waste into stable organic matter and lowering culture water's ammonia, nitrite, and nitrate levels. Biofloc will keep the water clean and limit disease risk in farm animals.
2. Feed efficiency: Wanja, Rebhung, & Sunadji (2020) showed that biofloc technology affects the efficiency of feed usage in milkfish. Because the microorganisms that dwell in the biofloc also offer nutrients to the farm animals, the biofloc technology system allows for less commercial feed. It will help minimize feed expenditures while reducing the environmental impact of surplus undigested meals.
3. Increased productivity: Because biofloc works as an additional source of nutrients in biofloc technology systems, higher population densities of farmed animals can be reached. It was consistent with the findings of Suhardianto and Hartari (2019), who discovered that the density of fish in ponds can rise thrice. This increased density has implications for improved productivity inside the same production unit, enhancing efficiency and profitability.
4. Environmental sustainability: Organic waste from farmed animals in conventional aquaculture systems can pollute the surrounding water. The risk of environmental pollution can be minimized by using biofloc technology since organic waste is transformed into solid biomass and repurposed as feed or organic fertilizer. Ma'in, Anggoro, & Sasongko (2013) state biofloc technology has reduced aquaculture waste.

Biofloc technology has achieved significant improvements in recent years. This method was first solely used in intensive fish farming. This technique, however, has grown into an efficient system for generating mixed fish and vegetables due to innovation and more profound research. Suhardianto and Hartari (2023) research found that biofloc catfish pond water can be used as a source of nutrition in mustard growth. Other studies show by Wiyoto, W., Siskandar, R., Dewi, R. K., Lesmanawati, W., Mulya, M. A., & Ekasari, J. (2023), Baskoro (2020) and Yustiningsih (2019).

It is achieved because biofloc technology is a cultivation approach that leverages microbial group growth in water as a source of nourishment for the organisms being cultivated. These microbes are a group of bacteria, algae, and protozoa that form brown or dark aggregates or flocs that contain critical elements like protein, vitamins, and minerals required by fish and plants. Fish and vegetables can thus grow in an integrated habitat in a biofloc system. Fish use This microbial floc as a natural food source, while the leftover feed and fish waste provide nutrients for growing vegetable plants.

This system has several advantages, making it an attractive alternative for meeting sustainable food needs and increasing resource efficiency. Sustainable food needs: Combination farming of fish and vegetables using biofloc can significantly contribute to meeting sustainable food needs. In this system, fish and vegetable plants grow together in a single container or pond, allowing for an efficient nutrient cycle. Fish waste, such as ammonia produced by fish waste, is a source of nutrition for vegetable crops. In contrast, vegetable plants absorb water-soluble nutrients and reduce excess ammonia and nitrate levels. In doing so, this system creates a symbiotic relationship between fish and plants, in which they mutually benefit from each other, resulting in sustainable food production.

Natural resource efficiency: Combined fish and vegetable aquaculture systems using biofloc can considerably improve resource efficiency. One of the primary benefits of this approach is that it requires less water than traditional growing methods. Biofloc generated in ponds creates stable water conditions, allowing for more efficient water utilization. Furthermore, nutrients from fish waste are reused by vegetable plants after being digested by microorganisms in biofloc. It decreases the need for extra fertilizers while reducing the environmental impact of excessive chemical fertilizer use. This approach can reduce waste and the environmental effects of conventional farming by utilizing resources efficiently.

Biofloc technology can play an essential role as an independent source of food for households to address food needs in urban contexts. Biofloc technology is an innovative method combining fish farming with various plants frequently produced hydroponically. Thus, this paper aims to demonstrate how biofloc technology can be employed as a type of home (family) size urban farming. The technology is to overcome the challenge of urban society's limited land to provide food independently by combining fish and vegetable production with the biofloc system. The continuity of micronutrients in biofloc ponds for the growth of plants and fish in ponds aligns with environmental sustainability and food security principles.

DISCUSSION

Aquaculture, or the cultivation of aquatic organisms, has grown important to address people's demands for marine and freshwater resources. Aquaculture specialists have been looking for innovative ideas to boost the fishing business's productivity, efficiency, and sustainability for many years. The creation of biofloc technology is one of the significant breakthroughs in this industry.

The biofloc technique is gaining popularity. This technique has enabled fish farmers to produce higher-quality goods more efficiently. However, "biofloc technology" may be unfamiliar to individuals new to this sector. As a result, before delving into the history of biofloc technology development, it is best first to provide a brief overview of the technology's fundamentals.

1. Biofloc technology

Aquaculture biofloc technology interacts with microbial and fish communities to overcome the two main difficulties in fish production: wastewater treatment and protein addition.

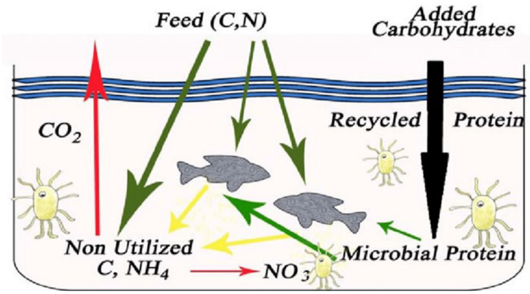
Wastewater from fish farming is high in dissolved and particulate matter, including excess nitrogen. Microorganisms utilize this extra nitrogen as a protein source by manipulating the C and N ratios (Das & Mandal, 2018).

Biofloc technology is a fish farming method that focuses on developing and using “flocs,” or colonies of microorganisms that coexist with fish in a culture system. This flock is made up of a variety of microorganisms, including bacteria, algae, protozoa, and other microscopic species. They dwell in aggregates with complex structures, often brown or orange, giving the water in biofloc systems a distinct appearance.

Biofloc technology works by utilizing microorganisms’ ability to transform waste products produced by fish into a source of high-value nutrients. When fish excrete waste such as ammonia, urea, and other organic chemicals, the microorganisms in the biofloc convert the waste into a safer and easier form for fish to ingest, such as nitrate and microbial protein. These processes, which include interactions between distinct types of bacteria, are known as nitrification and denitrification.

Microorganism colonies coexist with fish in the biofloc system. These microbes get nourishment from fish waste, and the fish get extra food from them. The presence of biofloc maintains the water quality in the aquaculture system because microorganisms assist in eliminating toxic compounds such as ammonia, which can damage fish.

The basic idea behind this technique is to create a nitrogen cycle by stimulating the growth of heterotrophic microorganisms, which digest nitrogenous wastes that can be used as feed by aquatic species being cultivated. Biofloc technology not only treats waste effectively, but it also feeds aquatic wildlife. The C:N ratio must be kept high by adding a supply of carbohydrates (molasses), and water quality is improved by producing high-quality single-cell microbial protein. Solid microorganisms proliferate and operate as water quality control bioreactors and protein food sources in these conditions. Because the heterotrophic substrate's microbial growth rate and production per unit is 10 times larger in bioflocs than in autotrophic nitrifying bacteria, hazardous nitrogen species are immobilized more quickly. This method is based on the flocculation principle in the system (Figure 1).



Sumber: *Avnimelech, 2014*

Figure 1. Scheme of The Biofloc Technology System (BFT)

2. The Rise of Biofloc Technology

Avnimelech (2014) provided the following year-by-year summary of the technological advances shift from conventional aquaculture to bioflocs:

a. 1960s period:

During this period, communities used conventional aquaculture systems for years before biofloc technology to raise fish and other aquatic organisms. Conventional system aquaculture is the dominant method of cultivating fish and other aquatic organisms. This system places fish or aquatic organisms in ponds or containers, usually filled with uncirculated water. The food given to the fish will produce waste, including uneaten food and fish excrement. This waste can cause the accumulation of substances harmful to fish and the surrounding environment. Before biofloc technology, communities have utilized conventional aquaculture techniques to cultivate fish and other aquatic species for years. Conventional system aquaculture is the most common way of raising fish and other aquatic organisms. Fish or aquatic organisms are placed in ponds or containers that are usually filled with uncirculated water in this arrangement. The fish food will generate waste, including uneaten food and fish feces. This waste can lead to the buildup of toxins that are toxic to fish and the environment (Avnimelech, 2014).

Alternatively, some are given a brief circulation in a pool or container filled with water. The water in the pond is either allowed to flow freely or is controlled by a basic circulation system. This strategy relies on regular water changes to ensure good water quality.

b. 1970s period:

In the 1970s, water-recirculating systems were created to improve the efficiency and sustainability of aquaculture. This system employs modern technology to improve water quality control through the employment of mechanical and biological filters, as well as the addition of supplemental oxygen. Although the RAS system offers numerous advantages, such as more efficient water use and improved water quality control, it also has downsides. One disadvantage is the high expense of running and maintaining this system (Avnimelech, 2014).

c. 1980s period:

In recent years, there has been a growing understanding of the need to manage water quality and fish health in aquaculture. However, awareness of water quality and its impact on fish growth could have been much higher. However, aquaculturists gradually realized the need to maintain high water quality to promote fish health and growth. Biofilter technology was created, which uses microorganisms to transform fish waste into safer substances. Biofilters aid in regulating ammonia and nitrite levels in pond water, allowing for more effective fish farming (Avnimelech, 2014).

d. 1990s period:

Biofilter technology has advanced and become widely used in aquaculture during the last decade. Using media like gravel, fiber, or synthetic materials promotes bacterial colonization in the biofilter. It helps to maintain improved water quality and minimizes the need for frequent water changes in traditional systems (Avnimelech, 2014).

e. 2000s period:

Biofloc technology was launched and implemented in Southeast Asia in the early 2000s, mainly in Indonesia, Thailand, and Vietnam. Farmers and academics in the region are starting to see the value of biofloc technology in enhancing aquaculture efficiency and resolving the environmental issues associated with aquaculture waste. Biofloc technology also aids in the reduction of reliance on artificial feeds and the improvement of water quality in aquaculture ponds. Biofloc gained popularity in the aquaculture industry in the years that followed. The term "biofloc" refers to a technology that combines the concept of a biofilter with the presence of microbe flocs, which act as organic waste processors in water. Bacteria, algae, and other minute organisms make up this floc. They aid in the precipitation trash and organic particles in water, considerably improving water quality.

Initially, biofloc was employed exclusively in shrimp aquaculture, as shrimp aquaculture systems present unique waste management issues. Biofloc aids in waste reduction and water quality improvement in shrimp cultivation ponds, enhancing shrimp growth and decreasing illness risk. Because of the success of biofloc in shrimp farming, this technology is also being used in fish farming. Biofloc can improve water quality and reduce waste's impact on fish. The biofloc method also allows for larger densities of fish cultivation, maximizing fish production in a limited space. It increases the efficiency and sustainability of fish aquaculture (Avnimelech, 2014).

Dr. Yoram Avnimelech is a prominent player in creating biofloc technology and its involvement in creating and popularizing it. He is the “Father of Biofloc” and a professor emeritus at the Technion-Israel Institute of Technology. He has contributed significantly to the advancement of biofloc technology, notably its application in shrimp farming. Dr. Avnimelech has authored several scientific papers and books. One of his books, “Biofloc Technology - A Practical Guide Book,” released in August 2009 (Avnimelech, 2014), has become the primary reference in this field. This book introduces the concepts of biofloc, water quality management, feed and nutrition control, and environmental management aspects in fish and shrimp farming, in addition to teaching the basic concepts of biofloc technology.

f. 2010s period:

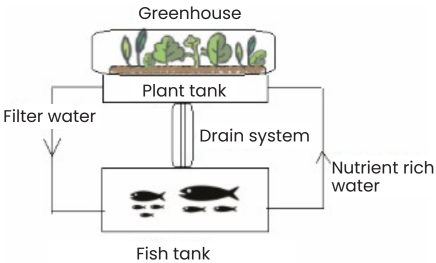
Biofloc technology is expanding and becoming more widely used in the aquaculture business. The benefits of biofloc include more efficient water consumption, less need for additional feed, and the capacity to handle fish waste efficiently. Biofloc also allows for higher densities of fish cultivation, enhancing productivity and efficiency (Avnimelech, 2014).

g. Currently (2023):

Biofloc is expanding and becoming a prominent approach in aquaculture. Fish farms are becoming more aware of the advantages of maintaining water quality, improving fish growth, and avoiding negative environmental impacts. Biofloc Technology (BFT) is constantly being enhanced via research and innovation to meet the increasing global demand for sustainable fish protein sources. It is envisaged that by transferring technologies from conventional aquaculture to biofloc, fish farming will become more efficient, sustainable, and ecologically benign (Avnimelech, 2014).

3. Integrated Biofloc Technology and Hydroponic

Aquaponics greenhouse is a symbiotic system that blends conventional aquaculture with hydroponic greenhouse. Animal waste accumulates in conventional aquaculture, increasing water toxicity, but in an aquaponics greenhouse, the fish waste is converted into plant nourishment by decomposing it into nitrates. Nitrogen is essential for all living organisms (Pratt & Cornely, 2014). The ammoniacal nitrogen excreted by fish is an essential nitrogen source for plant development (Timmons et al., 2002). The fish waste-carrying water is then transferred into the aquaculture system, where the nutrients are converted to nitrate by biological nitrification, denitrification, and plant absorption (Junge, 2009; Zou et al., 2016). Aquaponics is a potentially long-term technique for recycling nitrogen-rich effluent while producing excellent-quality crops such as vegetables and fish (Wongkiewa et al., 2016). Aquaponic is shown in Figure 2.



Sumber: *Pantazi et al., 2019*

Figure 2. The Schematic Aquaponics System

Aquaponics and biofloc-based aquaculture are environmentally benign methods of food production. Both intensive aquaculture systems heavily emphasize fertilizer recycling and water conservation (Boyd et al., 2020; Rocha, A.F., Biazetti, F.M.L., & Stech MR, S.R., 2017). FLOCponics share these traits. FLOCponics can become an additional means of mitigating the issues of global sustainable food supply by incorporating the principles of aquaponics and bioflocs. Pinho et al. recently proposed the term "FLOCponics" to identify and unite the systems formerly known as "BFT+hydroponics," "BFT+aquaponics," and "BFT+plant production."

According to FLOCponics researchers, adding hydroponics production to a BFT farm may increase economic diversity by producing additional value-added products (plants) and reduce the negative environmental impacts of biofloc-based production, such as nitrate and phosphorus accumulation in BFT culture and discharge through solids management (Emerenciano et al., 2021; Luo et al., 2020; Poli et al., 2019). BFT is also projected to provide relevant benefits in terms of agri-aquaculture productivity. The enhanced zootechnical performance recorded in BFT compared to RAS cultures (Luo, G., Gao, Q., Wang, C., & Al, E., 2014; Guemez-Sorhouet, E., Colmenares, H.V., Racotta, I.S., Naranjo, J., & Mercier, R., 2019), as well as the good impacts of BFT on animal nutrition and health (Dauda, 2020), indicating that FLOCponics may provide an advantage.

4. Animal and Vegetable Food Production through Biofloc Technology

Leafy vegetables and herbs, mainly lettuce and basil, are the most common vegetables grown in aquaponic systems. Because of the lengthier production cycle and desire for differing nutritional ratios, these systems are often less ideal for fruit vegetables. Many species, however, can be grown, particularly in media-based systems. Some of the more typically grown include lettuce, basil, coriander, spring onion, bok choy/pak choy, chiso, tomatoes and cucumbers, beets, okra, taro, and blueberries (Babatunde, A., Deborah, R. A., Gan, M., & Simon, T., 2022; Benjamin, E. O., Tzemi, D., & Fialho, D. S., 2021; Blanchard, 2019; Frost, 2019; Hambrey, J., Evans, S., & Pantanella, E., 2013; Matthews, 2017; Pattillo, 2021; Tetra, O. N., Yusuf, Y., Dewi, P., & Pardi, H., 2023; Ujjania, 2021).

These plants differ in terms of nutrient requirements and uptake. Fruit veggies have a greater nutrient demand and may require various nutrient levels at different stages of development. As a result, growing them successfully in aquaponic systems takes more work. Because basil and pak choy contain more nitrogen than lettuce or coriander, the balance between fish feeding and plant density may need to be adjusted correspondingly (Hambrey et al., 2013).

Although many fish can be farmed at great density in tanks in recirculated aquaculture or aquaponic systems, Tilapia (typically Oreochromis niloticus) is the favored species for tropical and subtropical environments. This is due to its ease of reproduction, tolerance of low Dissolved Oxygen (DO) levels (0.2 ppm), high Total Nitrate levels (>400 ppm), high Total Ammonia Nitrogen levels (>90 ppm @ pH 6.0), and low pH levels (5.0) (Hambrey et al., 2013). However, it should be noted that this species, like most others, demands DO >6ppm, pH >6, and low ammonia and nitrite levels for maximum growth and health (Hambrey et al., 2013).

In the variety of approaches used to raise them in captivity, Tilapia are exceptional. The following are examples of commercial operations: ponds, cages, raceways, tanks, net pens, lake ranching, freshwater, brackish water, seawater, aquaponics, plastic drums, and computer-controlled intensive recirculation systems. Production of this fish variety is higher than any other farmed fish. Production of Tilapia in metropolitan areas, high latitude regions, and even on the International Space Station has been made possible by using recirculating systems (Fitzsimmons, 2000, 2005).

One of the most significant fish species used in investigations on substitute ingredients has proven to be Tilapia. The most typical objective is to switch out fish meal and fish oils. Even though they are typically reasonably small elements in tilapia diets, farmers and researchers still wish to use locally available items and further minimize the amount of fish products in the diet (Zerai, B., Fitzsimmons, K.M., Collier, R.J., & Duff, G., 2008).

Another advantage that Tilapia have over many other common aquaculture species is their capacity to thrive in biofloc systems. According to Avnimelech (2009 and this volume), Tilapia are especially suited to flourish in biofloc conditions that would stress most other fish. This low-cost approach for growing healthy fish and lowering formulated feed costs could be an added benefit that keeps tilapia pricing competitive with other wild and farmed species (Fitzsimmons, K.M., Martinez-Garcia, R., & Gonzales-Alanis, P., 2011).

Despite its benefits, Tilapia may be a nuisance in some settings. Even in dense tank culture, it will rapidly reproduce, and the fry may spread to all regions of the recirculation system. They may wreak havoc on settling tanks or munch on roots in floating raft culture systems. Breeding will also lower the rate and quality of fish production.

Many different species have been employed in aquaponic systems. Catfish (e.g., *Clarias gariepinus*) have the added benefit of tolerating low oxygen and high nutritional levels. In contrast, common carp (*Cyprinus carpio*) is a generally strong fish that can be cultivated at high density and slightly lower temperatures (Hambrey et al., 2013). Ornamental fish can also be raised, but many demand clean water (though goldfish are robust). Trout thrive in cold regions; however, vegetable growth is likely to be poor at the temperatures this species prefers (11- 17^{o}C). Murray cod (*Maccullochella peeli peeli*, Mitchell), Asian barramundi (*Lates calcarifer*), mullet, perch, largemouth bass, Bester sturgeon, and grass carp are among the other species farmed.

Grass carp have been proposed to increase sustainability since they can be fed grass and waste vegetable matter instead of a high protein diet. However, the market for this bony and fairly tasteless fish could be better. As we will see below, the performance of vegetable production dramatically depends on the quality of fish feed. Grass is unlikely to be a suitable primary source of nutrients.

5. Biofloc Technology’s Benefits for Urban Communities

The ability to produce a diverse range of food products in a small urban area close to the consumer while minimizing environmental effects and generating social benefits is one of the critical long-term benefits of FLOCponics systems. Furthermore, the fact that these foods are healthful, pesticide-free, and available in a wide variety (fish and vegetables) makes FLOCponics a crucial technology in the food production area (Pinho et al., 2021) for now and future demand.

CONCLUSION

1. Biofloc technology offers an integrated approach to animal and vegetable food production that fulfills urban societies' nutritional needs.
2. It is feasible to build aquaculture and hydroponic systems in a closed-loop process that saves resources by exploiting the capacity of selected bacteria in biofloc technology.
3. Biofloc technology, with its closed-loop approach, provides sustainable and scalable solutions to urban community concerns.
4. The fact that urbanization is increasing occasionally will allow us to develop a more robust and food-secure society through biofloc technology.

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