Available online www.worldscientificnews.com

World Scientific News

An International Scientific Journal

WSN 207 (2025) 78-88 EISSN 2392-2192

Reviews: Application of Biofloc Technology in Tilapia Cultivation (*Oreochromis Niloticus*)

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ABSTRACT

FAO (2006) mentions some of the main producers of tilapia, such as Southeast Asia, East Asia, Africa, Latin America, and North America. China is one of the largest tilapia exporting countries in the world, with a total export of 402,000 tons, generally the tilapia exported is used as tilapia fillet, which costs up to 4.6 USD, until the total profit reaches 26 trillion rupiah. In the Southeast Asian region, tilapia exports reached 3.3 million tons in 2012 and one of the largest tilapia producing countries is Indonesia. Generally, tilapia is exported to various countries in the United States, the European Union, and the Middle East. One of the technologies applied in tilapia cultivation is biofloc technology. Biofloc technology is a technology that utilizes microorganisms and organic matter contained in waters to improve the quality of aquaculture media. This technology utilizes a symbiosis of mutualism between heterotrophic organisms that will produce flocs in the cultivation medium that function in increasing biosecurity in aquaculture ponds, increasing FCR, improving water quality, water use efficiency during the maintenance period, and land use efficiency. Common problems faced in the application of tilapia biofloc are water quality management, tilapia growth management, fish feed management, and waste management. Several technological engineering techniques are used for more optimal management of tilapia cultivation in biofloc, such as monitoring water quality using the Internet of Things (IoT) and the use of automatic feeders for automatic feeding that is adjusted to the time and eating habits of tilapia. In addition, tilapia cultivation using biofloc can also be used as one of the educational tours for the community.

Keywords: Tilapia needles, biofloc, water quality management, culture management, Internet of Things, Automatic Feeders

(Received 8 July 2025; Accepted 15 August 2025; Date of Publication 13 September 2025)

1. INTRODUCTION

The contribution of aquaculture to food security has increased every year through increased production, animal protein consumption, job creation, income increase, and regional development. One of the aquaculture segments is tilapia cultivation. Another reason is that tilapia is able to adapt easily to artificial feed. Black tilapia is a species from the Chiclidae family, the genus *Orechromis* , tilapia is favored by the Indonesian people because it has a higher protein content than goldfish and eels (Aini, 2019). The nutritional content of tilapia can be seen in **Table 1**. FAO (2006) mentions some of the main producers of tilapia, such as Southeast Asia, East Asia, Africa, Latin America, and North America. China is one of the largest tilapia exporting countries in the world, with a total export of 402,000 tons, generally the tilapia exported is used as tilapia fillet, which costs up to 4.6 USD, until the total profit reaches 26 trillion rupiah. In the Southeast Asian region, tilapia exports reached 3.3 million tons in 2012 and one of the largest tilapia producing countries is Indonesia. Generally, tilapia is exported to various countries in the United States, the European Union, and the Middle East. One of the technologies applied in tilapia cultivation is biofloc technology. Biofloc technology is a technology that utilizes microorganisms and organic matter contained in waters to improve the quality of aquaculture media. This technology utilizes a symbiosis of mutualism between heterotrophic organisms that will produce flocs in the cultivation medium that function in increasing biosecurity in aquaculture ponds, increasing FCR, improving water quality, water use efficiency during the maintenance period, and land use efficiency (El Sayed, 2020; Simangunsong and Khoriulanam, 2022).

Biofloc technology is one of the alternatives to aquaculture waste, this is because this technology provides additional protein feed for cultivated animals so that it can increase feed growth and efficiency. Biofloc technology has the principle of adding organic carbohydrates to the maintenance medium to increase the C/N ratio by stimulating the growth of heterotroph bacteria that can assimilate organic nitrogen into bacterial biomass. Carbohydrates commonly used in biofloc technology are tapioca flour, bran flour, cornstarch, starch flour, and so on. Another effort that can be made to prevent the harmful effects of aquaculture waste due to feed residues, problems with limited feed, water, and land, is RWS (*Red Water System*), this system uses probiotic bacteria as an effort to prevent microbial infections and at the same time as a substitute for the use of antibiotics. Probiotics in this system are defined in the form of intact microbial cells to increase the utilization of feed nutrients or increase their nutritional value (Zizhong *et al.,* 2009), the RWS system itself is a development of a biofloc system that utilizes Lactic Acid Bacteria to decompose the remaining organic matter in the waters into substances that are used for fish in a cultivation system (Yulvizar *et al.,* 2014). The development of the times that is increasingly advanced makes tilapia biofloc technology has many developments and engineering both biologically and system engineering. However, this certainly cannot be separated from the problems faced, which of course require a solution to optimize tilapia cultivation.

Nutrition	Nutritional Content
Carbohydrates	0.32 grams
Protein	16.79 grams
Fat	0.10 grams
Calcium	4,782 mg
Phosphorus	610 mg
Iron	2.76 mg

2. METHODS

The analysis of this article is sourced from a literature study. Literature studies are closely related to references and other theoretical studies that are related to values, cultural norms that are developing in the social conditions being studied, other things literature studies are also very important factors for the research process, this is because research is inseparable from scientific literature (Sugiyono, 2017). Literature studies are used to increase data and information by studying literature materials, such as those related to the theme of discussion (Yalina *et al*., 2020). Related techniques can also be referred to as literature studies, namely by searching for literature sources that contain theories contained in scientific papers that have been published or have not been or can be called hard copies or soft copies in electronic books (e*books*), theses, and e-journals.

3. RESULTS

3.1. Application of Biofloc Technology in Tilapia Cultivation

Biofloc technology is a technology that utilizes microorganisms that function as an additional source of protein for cultivated organisms. Biofoloc is generally formed by different types of beneficial microbes. Generally, these microorganisms are microorganisms that can convert residual substances in the cultivation environment into additional energy sources (Ministry of Agriculture, 2019). Scheneider *et al.,* (2006) stated that biofloc is a process of forming organic and inorganic compounds consisting of carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and a little phosphorus (P), these compounds will form a mud-like floc formed from floc-forming bacteria that synthesize polyhydroxy alkanoate biopolymers as biofloc bonds. Heterotroph bacteria contained in the cultivation medium will play a role in the decomposition of organic nitrogen waste from feed residues and metabolism to be broken down into bacterial biomass (Febriyanti *et al.,* 2019).

Tilapia has many strains, which can be cultivated. However, generally, tilapia tilapia is generally used in biofloc technology. Tilapia tilapia is widely used because it has optimal ability to manage and utilize flocs in the cultivation medium (E Sayed, 2020). Efforts to increase fish farming yields are usually carried out by intensive system cultivation. However, there are many challenges in intensive cultivation, such as maintaining the quality of cultivation water, which is quite tricky. The biggest problem of intensive cultivation systems is the residual feed and metabolic residues of organisms that increase as stocking density increases.

If this is not handled in the right way, then the rest of the feed and metabolic residue of the aquaculture organism will settle at the bottom of the aquaculture pond and become one of the sources of ammonia that is toxic to the waters if the level is high (Marlida, 2020). One of the bacteria that is usually found in the biofloc system is *Nitrosomonas* and Nitrobacter, which function to convert nitrite from toxic ammonia into nitrates that can be used by microalgae in cultivation media as one of the components of photosynthesis (Crab *et al.,* 2012).

Some of the stages that must be prepared in making tilapia biofloc include the preparation of culture containers, the preparation of culture mediums, and culture management. Nika fish culture containers usually have a capacity of 80 liters filled with fresh water, equipped with an aerator, in the middle of the container, is placed a diffuser to allow water to rotate continuously. Tilapia is first measured in weight and acclimatized first before entering the cultivation container**.** The culture medium must first be ensured to get appropriate aeration and then given probiotic bacteria in the form of EM-4, usually, for 60 liters, a dose of EM-4 as much as 0.3 ml is used in 200 ml of water, then given molasses as much as 15 ml dissolved in 200 ml, homogenized. Then given tempeh yeast 0.5 grams dissolved in 200 ml, the last addition is 12 grams of dolomite dissolved in 200 ml of water.

3.2. Biofloc Culture Management

When the culture media is ready, tilapia is put in and fed as much as 3% of body weight, after 1 week the fish is only fed as much as 1% of body weight. For salinity management, it was increased from the first week to the next, initially 7 and increased to 10 in the second or third week. Water quality measurements are carried out every day, measurements include DO, temperature, nitrates and nitrites. If the ammonia content is high, then the carbon source should be added and the protein reduced. If the nitrite is too high then aeration must be evaluated and the sediment sucked out. In addition, another factor that must be considered in aquaculture management is water quality management. The temperature of the water used should be in optimal condition. The optimum temperature for tilapia cultivation using the biofloc technique ranges from 26-30^{oC} $^{(}$Ombong and Salindeho, 2016), this condition will maintain floc production in the pond. With the high floc production in the pond, the need for commercial feed is also reduced because most of the tilapia protein needs are met from the consumption of floc in the pond (Silviana, 2021). In water quality management, the thing that must be considered in addition to maintaining pH, temperature, and DO is the management of organic materials, especially organic materials that have certain levels of toxicity, one of which is ammonia. The maximum level of ammonia in aquaculture water is 0.03 mg/L, in this figure, ammonia is still expressed within the safe threshold limit for the life of organisms in aquaculture ponds (Rostro *et al.,* 2012).

In addition to ammonia, another organic compound that must be considered is nitrite, the maximum nitrite level for tilapia cultivation is 2 mg/L (Ombong and Salindeho, 2016). The application of biofloc techniques is reported to be able to maintain the temperature of the maintenance water at optimal conditions in the range of 26-28 ºC. The value of dissolved oxygen in water is in the range of 5.7-6.8 mg/L. The temperature range in the cultivation medium is (26-28)°C, for other water quality parameters such as ammonia, it is no more than 1.5 (Crab, 2010), for nitrites in biofloc technology, the quality standard is 2 mg/l, and for nitrate, quality standard is 30 mg/l (Oktavia *et al.,* 2012). The use of this technology is reported to be effective in maintaining the pH of maintenance water, avoiding avoids an acidic atmosphere, which is in the range of 7.0-7.9 and maintaining ammonia levels in the pond at 0.063-0.03 (Sitorus et al., 2019).

The use of commercial EM4 probiotics has been proven to maintain the quality of pond water. However, the application of too high doses of EM4 probiotics can reduce the quality of fish rearing water, which is harmful to survival and will inhibit fish growth (Suprianto et al., 2019). Another effort used in maintaining ammonia and nitrate levels is to add molasses and rice flour with a concentration of 1:1, at the end of the observation period of 20 days, tilapia cultivated using BFT experienced an increase in average body weight and a better feed conversion ratio. Tilapia cultivation management with a biofloc system does not only focus on the management of the culture pond but must also pay attention to the waste produced from the culture process carried out. Fishery waste with a high content of organic matter, if disposed of into public waters without first being treated, will have a bad impact on the environment. Thalib *et al.,* (2016) stated that tilapia waste can be reused as a medium for catfish cultivation, which has a fairly high adaptability in an environment with high levels of organic compounds and minimal dissolved oxygen.

3.3. Tilapia Growth Management in Biofloc Systems

The growth of tilapia with the biofloc system is generally faster than the growth of tilapia in the conventional cultivation system, with daily growth reaching 2.11% (Ombong *et al.,* 2016). Other studies also mentioned that there is an increase in salinity treatment during culture is able to increase the daily growth rate by a range of 1.85 – 2.57% (Ekasari, 2009). Some of the steps or focuses that need to be considered by cultivators in the growth of tilapia using the biofloc system are to pay attention to stocking density, increase fish survival, increase the food conversion ratio (FCR), maintain water quality, and prevent dangerous diseases.

In the cultivation of tilapia, the biofloc system, with the characteristics of tilapia that has a fairly sharp dorsal fin is a challenge in the cultivation of tilapia with the biofolok system. Generally, the stocking density of tilapia in the biofloc system is 100 fish/m^3 for black tilapia measuring 3-4 cm, which will produce production productivity of 25-30 kg/m^3 (Maryam, 2010). The normal growth rate of tilapia in the biofloc system reached 2.11% with an absolute growth of 5.47 grams after 30 days of maintenance (Ombong *et al.,* 2016). Tilapia growth in biofloc given a dose of EM4 probiotic of 0.007 ml/L can increase fish weight by 5.30 grams and fish length by 2.58 cm from the initial weight and weight of fish before being given EM4 probiotics (Suprianto *et al.,* 2019). Biofloc technology can also increase fish survival, even reaching 100%, research conducted by Azim and Little (2008) shows that the survival of tilapia cultivated in the biofloc system reaches 100%, while research conducted by Ahadiftita *et al.,* (2016) shows that the survival of tilapia cultivated in the biofloc system is at 47%, this difference in survival rate is influenced by various things such as the type of feed, the type of bacteria or probiotics used, the number of fish reared, the density of fish reared, the equipment used, and other internal and external factors that directly and indirectly affect the cultivation process and the survival rate of fish.

Efforts to improve tilapia survival in biofloc system cultivation are carried out through the addition of probiotics to biofloc pond water. Simangunsong and Anam (2022) stated that the addition of 0.007 ml/L EM4 to biofloc pond water can increase tilapia survival by 77%. However, if the EM4 dose is added by 0.008 and 0.009 the survival of tilapia is lower than 77%. This shows that the probiotics used in probiotic technology must also be adjusted to the conditions of the culture being carried out. The probiotics used can be one of the limiting factors in the survival of tilapia in the cultivation of biofloc systems.

Hisano *et al.,* (2021) researched the use of biofloc technology compared to the use of RAS (Resirculating Aquaculture System) cultivation, tilapia cultivation was carried out for 60 days with a ratio of fish density (*n* = 64; 7.29 ± 0.67) with a water volume of 150 liters. The temperature in the aquaculture pond was maintained in the range of 26-27oC. The results showed that the best growth response was found in the BFT treatment, supported by feed efficiency in tilapia fingerlings. Several efforts are made to overcome the problem of scattered solids that are inversely proportional to the survival rate, generally using the addition of certain materials to increase the survival rate in stocking densities that are quite high. El Hawarry *et al.,* (2021) researched the addition of several carbon sources used in BFT with different densities, namely 140 fish/m3 and 280 fish/m3, the carbon sources used in BFT are unit-glycerol, molasses, and flour. The results showed that the treatment of adding a carbon source in the form of unit-glycerol showed a positive growth response and feed efficiency compared to the treatment of providing other carbon sources.

Increasing the survival of tilapia in the juvenile phase is also one of the important things, the juvenile phase of tilapia is in a fairly sensitive phase. Several efforts have been made, such as a study conducted by Haraz *et al.,* (2023) which examined the administration of probiotics of *the Bacillus subtilis* and *Lactobacillus acidophilus* types in juvenile tilapia biofloc, tilapia density of 120 fish/m3 and the average juvenile initial weight is 16.72 grams/fish, using a C:N ratio of 0:1; 10:1; 20:1, the final results of the study show that C: N ratio of 10:1 and administration of *B. subtilis* probiotics showed better growth performance and feed utilization compared with control conditions. C:N ratio is one of the limitations of efficient BFT, an appropriate C:N ratio boosts a heterotrophic bacterial community that may reach 109 cells/ml. These bacteria assimilate the potentially harmful ammonium and unconsumed food into long-term beneficial microbial biofilm rich in protein that is easily accessible by the fish, improving fish growth performances. Research on the optimal C:N ratio treatment has been studied. Aboseif *et al.,* (2022) researched the variation of different C:N ratio treatments for optimizing tilapia cultivation using biofloc with a total volume of 10 liters of aquaculture water and a culture period of 70 days, the C:N ratio used is 10:1; 8:1; 6:1; and 4:1, the results of the study show that the C:N ratio which shows optimal results on tilapia growth and feed utilization is in the C treatment: N ratio 8:1.

3.4. Common Problems That Occur in Tilapia Cultivation Using Biofloc Technology

The application of biofloc technology in supporting effective cultivation activities is still in the development period, especially the effectiveness of its performance, the main thing that needs to be considered, in addition to the quality of water or cultivation media, stocking density or density of cultivation organisms also needs to be considered. The density of aquaculture organisms must be well considered, as this will be related to various aspects of the health of aquaculture organisms, especially affecting the regulation of water quality and the regulation of the overall operational costs of cultivation. Several previous studies have observed the optimum density of tilapia cultivation in biofloc technology. Vieira *et al.,* (2019) researched several tilapia density treatments in a 250 L aquaculture container with a fugsional water volume of 150 mL using biofloc technology with a measured water recirculation system, salinity, and pH respectively 5 and 7.5. Aquaculture commodities (tilapia) were fed with commehassial feed containing 35% protein, 5% lipid, and 7% fibrous matter. For the maintain biofloc used a C:N ratio of 20:1, the carbon used in the system comes from brown sugar that has gone through the chlorine-free stage first.

This study concludes that with the culture system and conditions using biofloc technology with specific culture conditions that have been detailed, it produces an effective tilapia cultivation density of 800 fish/m3, the tilapia production efficiency is achieved at 276.49 which shows a figure three times the control treatment, which is 248 fish/m3. Manduca *et al.,* (2021) examined the influence of different tilapia stocking densities in biofloc systems with minimal water change. This study uses biofloc technology with a volume of 1000 L, the volume of water fumgsional is 800 L. Tilapia that is cultivated is fed three times a day with commercial feed containing 32% protein. The condition of several water quality parameters that during the culture process is maintained in near-optimal conditions. This study resulted in the conclusion that the final biomass produced was 36.86 kg/m^3.

A disadvantage that cultivators must pay attention to when applying biofloc technology in aquaculture is poor fish growth. Azim and Little (2008) reported that fish production cultivated in biofloc technology has a fairly low feasibility standard due to poor growth, this is quite a concern, so that it requires better feed management and quality improvement. Yunianto and Suryandari (2022) stated that biofloc cultivation has a low success rate, this is because, along with the development of fish, biofloc ponds are also getting denser and the color of the water is getting thicker and dirtier. Water quality also declines and often leads to fish deaths. However, the success of biofloc technology in fish production with minimal water change is worth reckoning, but several records related to feed management and water quality still need to be improved and considered for the continuity and success of aquaculture using biofloc technology. Of course, in dealing with this, it is not enough to only play the role of cultivators as the main actors. Synergy from policy makers, researchers, and cultivators is needed to determine optimal cultivation conditions and minimize cultivation management failures for maximum production of cultivation products.

3.5. Development and Engineering of Biofloc Systems in Optimizing Tilapia Cultivation

Biofloc cultivation is highly dependent on water quality, poor water quality will result in the health and survival of cultivated fish. Changes in water quality are caused by changes in weather and the input of organic matter sourced from feed residues and metabolic waste. This requires a quick solution to deal with changes in water quality that experience rapid fluctuations in aquaculture ponds. Water quality standards are in accordance with the SOP of the Ministry of Fisheries and Marine Affairs of the Republic of Indonesia, with dissolved solids content at $50 < TDS < 600$mg/l, dissolved oxygen with DO>5mg/l content, water acidity with a content of $6 < pH < 8$, temperature with a content of $20 < T < 30$°C and ammonia with a content of $NH_3 < 0.2$ mg/l, When water quality conditions are not in accordance with the minimum level, it requires a quick response to deal with changing water quality problems, for example, the use of aeration to increase dissolved DO and other adjustments that can be made by cultivators. However, the biggest obstacle is that cultivators do not know when to take the right actions or take the right precautions related to fluctuations in the quality of aquaculture water. So, a tool is needed that can quickly measure water quality accurately and in real time. Nowadays, the use of Internet of Things technology in the field of cultivation has been widely used. Sumantri (2024) researched the development of a water quality control and monitoring system in the biofloc system in tilapia ponds at MJA Farm Cikampek using the Internet of Things (IoT), the results of the study showed that the accuracy of water quality measurement reached 97.4% with an error percentage of 2.56%. The data measured using IoT devices will be transmitted by computers through a cloud system and provide real-time warnings regarding changes in water quality in aquaculture ponds.

A similar study was conducted by Ashari *et al.,* (2022) regarding the application of IoT-based tilapia farming monitoring and control systems, and the results of the study showed that the use of DS18B20 temperature sensors and DF sensors of the Robot PH Meter V 1.1 had good accuracy, namely 95.87% and 98.28%, respectively. Meanwhile, the Gravity TDS Meter V 1.0 sensor is still not good enough, where the accuracy percentage obtained is 93.44%. The use of IoT connected to the cultivator's gadget will make it very easy for cultivators to monitor and control the quality of cultivated water without having to come to the cultivation site or make observations all day long to find out the condition of the quality of the cultivated water. Real-time data from water quality measurements using IoT will be sent through the internet connected to the cultivator's gadget device. If there is a drop in water quality, the cultivator will quickly respond to handle the water quality changes that occur.

Tilapia cultivation engineering using biofloc technology is also applied to tilapia feed management. Feeding using an automatic feeder can make it easier for cultivators. Cultivators do not always have to be on guard and alert around the pond to determine when the fish are hungry and need to eat. The use of automatic feeders can also be adjusted to the time habits and eating behavior of tilapia. For example, tilapia tends to eat when the sun begins to rise and the sun begins to set, not only that, adjustment of fish behavior is also used in this automatic feeding. Research conducted by Chaidir *et al.,* (2025) examined the use of aoutomatic feeders in tilapia biofloc compared to conventional feeding. The results of the application of technology show that the feed conversion ratio reached 97.6%, the survival rate reached 94.4%, and the specific growth rate reached 3.58%. This is better compared to several other treatments in fish culture, so it can result in faster harvest results with efficient use of feed and maximum harvest quantity.

The development of tilapia cultivation through biofloc is not only related to cultivation management intended for a better system and more optimal yields. However, the development of tilapia cultivation through the biofloc system in various regions in Indonesia has also developed into one of the attractions of educational tourism for the community. The Ministry of Maritime Affairs and Fisheries of the Republic of Indonesia released a projection of data on fish consumption by the Indonesian people reaching 50 kilograms per year, further explaining that the fisheries sector will fully depend on the aquaculture sector compared to the fishing sector, considering that the condition of some Indonesian sea waters has exceeded the catch threshold. In addition, through cultivation, the community can also help preserve fish species. One of them is Tulungrejo Village, which has abundant freshwater resources, so it can be used as one of the development and application of freshwater fish cultivation. Through the assisted village grant program, Tulungrejo Village was proclaimed as one of the freshwater fisheries cultivation centers using biofloc technology. As a result, after evaluating and monitoring the biflok tilapia cultivation center program in Tulungrejo Village, this village developed into a pilot village educational tourism and the formation of a fish cooperative that makes it easier for cultivator groups to rotate and market their crops (Silviana *et al.,* 2021).

4. CONCLUSION

Biofloc technology is a technology that utilizes microorganisms that function as an additional source of protein for cultivated organisms. Biofoloc is generally formed by different types of beneficial microbes. Generally, these microorganisms are microorganisms that can convert residual substances in the cultivation environment into additional energy sources. In the cultivation of tilapia, the biofloc system, with the characteristics of tilapia that has a fairly sharp dorsal fin is a challenge in the cultivation of tilapia with the biofolok system. Generally, the stocking density of tilapia in the biofloc system is 100 fish/m^3 for black tilapia measuring 3-4 cm, which will produce production productivity of 25-30 kg/m^3. Common problems faced in the application of tilapia biofloc are water quality management, tilapia growth management, fish feed management, and waste management. Several technological engineering techniques are used for more optimal management of tilapia cultivation in biofloc, such as monitoring water quality using the Internet of Things (IoT) and the use of automatic feeders for automatic feeding that is adjusted to the time and eating habits of tilapia. In addition, tilapia cultivation using biofloc can also be used as one of the educational tours for the community

References

[1] Aini, N. (2019). *The nutritional content of tilapia is compared to other consumption fish*. Journal of Fisheries and Marine Affairs, 11(2), 55–60.

[2] El-Sayed, A. F. M. (2020). *Tilapia culture* (2nd ed.). Academic Press.

[3] FAO. (2006). *State of world aquaculture 2006*. FAO Fisheries Technical Paper No. 500. Rome: Food and Agriculture Organization of the United Nations.

[4] Simangunsong, A. F., & Khoriulanam, A. (2022). Application of biofloc technology in tilapia (*Oreochromis niloticus*) cultivation to improve production efficiency. *Indonesian Aquaculture Journal*, 21(1), 12–20.

[5] Zizhong, X., Rejmanek, D., & Rowley, R. J. (2009). Probiotics in aquaculture: A review of definitions, mechanisms, and current research. *Aquaculture Research*, 40(3), 256–264. https://doi.org/10.1111/j.1365-2109.2008.02101.x

[6] Yulvizar, C., Muchlisin, Z. A., & Murda, T. (2014). Application of probiotics in the Recirculating Water System (RWS) system to improve water quality and growth of tilapia (*Oreochromis niloticus*). *Scientific Journal of Marine and Fisheries Students Unsyiah*, 1(1), 1–7.

[7] Sugiyono. (2017). *Mixed Research Methods*. Bandung: Alfabeta.

[8] Yalina, L., Ramadhan, D., & Nurhayati, R. (2020). Literature study in qualitative research methods. *Indonesian Journal of Social Education*, 8(1), 45–52.

[9] Febriyanti, E., Susilowati, T., & Nuryati, S. (2019). The effectiveness of biofloc in improving water quality and feed efficiency in fish farming. *Indonesian Aquaculture Journal*, 18(2), 150–158.

[10] Ministry of Agriculture (Kementan). (2019). *Technical instructions for fish farming biofloc system*. Directorate General of Aquaculture Fisheries, Ministry of Marine Affairs and Fisheries.

[11] Schneider, O., Scott, V., Eding, E. H., & Verreth, J. A. J. (2006). Analysis of nutrient flows in integrated intensive aquaculture systems. *Aquacultural Engineering*, 32(3–4), 379–401. https://doi.org/10.1016/j.aquaeng.2004.09.001

[12] Crab, R., Defoirdt, T., Bossier, P., & Verstraete, W. (2012). Biofloc technology in aquaculture: Beneficial effects and future challenges. *Aquaculture*, 356–357, 351–356. https://doi.org/10.1016/j.aquaculture.2012.04.046

[13] Ombong, N. N., & Salindeho, N. (2016). Effect of temperature on the growth of tilapia (*Oreochromis niloticus*) in the biofloc system. *Journal of Tropical Fisheries Science and Technology*, 4(2), 55–61.

[14] Silviana, R. (2021). The effectiveness of biofloc in reducing feed use in tilapia farming. *Journal of Sustainable Aquaculture*, 10(1), 22–29.

[15] Rostro, C. I., Ibarra, L. E., Páez-Osuna, F., & Espinosa, R. (2012). Acute toxicity of ammonia to juvenile *Litopenaeus vannamei* in low salinity conditions. *Aquaculture Research*, 43(3), 447–453. https://doi.org/10.1111/j.1365-2109.2011.02850.x

[16] Thalib, A., Setiawan, I. D., & Rahman, H. (2016). The use of tilapia cultivation waste as a medium for maintaining catfish (*Clarias sp.*). *Journal of Fisheries and Marine* Affairs, 7(1), 45–52.

[17] Ekasari, J. (2009). Evaluation of the biofloc system in tilapia (*Oreochromis niloticus*) cultivation by salinity manipulation. *Indonesian Aquaculture Journal*, 8(1), 1–10.

[18] Ahadiftita, R., Suharyanto, H., & Widyastuti, R. (2016). The effect of probiotic administration on tilapia survival in the biofloc system. *Indonesian Aquaculture Journal*, 15(1), 10–18.

[19] Azim, M. E., & Little, D. C. (2008). The biofloc technology (BFT) in indoor tanks: Water quality, biofloc composition, and growth and welfare of Nile tilapia (*Oreochromis niloticus*). *Aquaculture*, 283(1–4), 29–35. https://doi.org/10.1016/j.aquaculture.2008.06.036

[20] Maryam, S. (2010). Tilapia cultivation of biofloc system: Technical guide. *Sukabumi Freshwater Aquaculture Development Center*.

[21] Suprianto, E., Hartati, H., & Sutrisno, B. (2019). The effect of the addition of EM4 probiotics on tilapia growth in the biofloc system. *Journal of Aquaculture Fisheries*, 7(2), 45–52.

[22] Hisano, H., Nakada, M., Kimura, D., Yamamoto, A., & Furuita, H. (2021). Comparison of biofloc and recirculating aquaculture systems on water quality, growth performance, and microbial communities in Nile tilapia (*Oreochromis niloticus*) culture. *Aquaculture Reports*, 20, 100718. https://doi.org/10.1016/j.aqrep.2021.100718

[23] El-Hawarry, W. N., Abouelezz, F. M. K., El-Haroun, E. R., & Zaki, M. A. (2021). Effects of different carbon sources on water quality, growth performance, and feed utilization of Nile tilapia (*Oreochromis niloticus*) cultured under biofloc system with different stocking densities. *International Aquaculture*, 29, 1755–1771. https://doi.org/10.1007/s10499-021-00725-2

[24] Haraz, M. E., El-Greisy, Z. A., Abdelhamid, M. M., & Mahmoud, M. A. (2023). Effects of carbon to nitrogen ratios and probiotic supplementation on growth performance, feed efficiency, and water quality in Nile tilapia (*Oreochromis niloticus*) cultured in biofloc system. *Aquaculture International*, 31, 563–578. https://doi.org/10.1007/s10499-023-00945-y

[25] Vieira, F. D. N., Mouriño, J. L. P., Jatobá, A. M. B., Buglione-Neto, C. C., & Martins, M. L. (2019). Effects of stocking density on the performance and health of Nile tilapia (*Oreochromis niloticus*) cultured in biofloc technology with low salinity water. *Aquaculture*, 512, 734282. https://doi.org/10.1016/j.aquaculture.2019.734282

[26] Manduca, F. G., Michelato, M., Furuya, W. M., & Furuya, V. R. B. (2021). Stocking density of Nile tilapia in biofloc system with minimum water exchange. *Aquaculture Research*, 52(6), 2710–2719. https://doi.org/10.1111/are.15148

[27] Yunianto, A. A., & Suryandari, E. (2022). Challenges in fish farming biofloc system in intensive ponds. *Journal of Tropical Fisheries*, 10(1), 33–40.

[28] Sumantri, R. (2024). Development of IoT-based water quality control and monitoring system in biofloc system tilapia cultivation at MJA Farm, Cikampek. *Journal of Fisheries and Marine Technology*, 12(1), 15–24.

[29] Ashari, D., Prasetyo, A. D., & Maulana, H. (2022). Application of IoT-based water quality monitoring and control system in tilapia cultivation. *Journal of Aquaculture Technology and Engineering*, 11(2), 105–112.

[30] Chaidir, A., Hidayat, M. R., & Lestari, D. (2025). The effect of the use of automatic feeders on feed efficiency and tilapia growth in the biofloc system. *Journal of Digital Aquaculture Technology*, 13(1), 40–49.