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The Impact of Silica Addition on Floc Volume Density in the Biofloc System for Juvenile Red Tilapia (*Oreochromis niloticus*)

Ryan Mochamad Ihsan [a*], Ujang Subhan [b], Lantun Paradhita Dewanti [b] and Iskandar [b]

[a] Faculty of Fisheries and Marine Science, Padjadjaran University, Indonesia.
[b] Fisheries Department, Faculty of Fisheries and Marine Science, Padjadajran University, Indonesia.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Biofloc technology is a solution to the problem of waste management in aquaculture. Biofloc systems are beneficial because they not only reduce inorganic nitrogen waste from feed residues and fish excrement but also produce flocs. The aim of this research is to determine the effect of silica addition on floc volume density in the biofloc system for juvenile red tilapia. The research was conducted from January to March 2024 at the Center of Excellence in Science and Technology (PUI-PT) for Functional Nano Powder at Padjadjaran University. This study uses a Completely

**Corresponding author: Email: ryan20004@unpad.ac.id;*

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Randomized Design (CRD) experimental method with four treatments and three replications. The treatments used were (A) control, (B) 15 ppm silica, (C) 20 ppm silica, and (D) 25 ppm silica. The study used cylindrical containers with a capacity of 19 liters filled with 15 liters of water, a stocking density of 10 juvenile red tilapia per cylinder, with the juvenile measuring 3-4 cm and weighing 3-4 g. The parameters observed were floc volume density and water quality. The data on floc volume density and water quality were analyzed descriptively. The results showed that the addition of 25 ppm silica in the biofloc system was the best treatment for floc volume density. This was evidenced by the results in treatment D (25 ppm) achieving a floc volume density of 26.5 ml/L, which falls into the dense category. Therefore, the addition of silica concentration in the biofloc system can increase floc volume density.

Keywords: Biofloc; floc; diatom; silica.

1. INTRODUCTION

Biofloc technology is a new alternative to address water quality issues in aquaculture, adapted from conventional domestic waste treatment techniques [1]. The main principle applied in this technology is water quality management based on the ability of heterotrophic bacteria to utilize organic and inorganic nitrogen present in the water. Under balanced carbon (C) and nitrogen (N) conditions in the water, heterotrophic bacteria will use nitrogen, both in organic and inorganic forms, present in the water for biomass formation, thereby reducing the nitrogen concentration in the water [2].

The formation of biofloc by bacteria, particularly heterotrophic bacteria, is generally aimed at enhancing nutrient utilization, avoiding environmental stress, and predation [2]. Bacterial flocs consist of a mixture of various types of microorganisms (floc-forming bacteria, filamentous bacteria, fungi), suspended particles, various colloids and organic polymers, different cations, and dead cells, with sizes ranging from 100 to 1000 µm [3].

Aquaculture systems using biofloc technology heavily depend on the structure of the microbial community within them. The microbial community consists of a heterogeneous array of microorganisms such as plankton (both phytoplankton and zooplankton), bacteria (floc formers and filamentous bacteria), living aggregates, bacterivores, colloidal particles, organic polymers, and dead cells [4]. Floc volume density is a key factor that determines the success of the biofloc system, as denser flocs are more effective in capturing particles and nutrients, and providing an additional food source.

One of the challenges in managing a biofloc system is ensuring that the flocs form with optimal volume and density. The biofloc system must be maintained to achieve a balance in decomposition, nitrification, denitrification, and the utilization of flocs by cultured organisms, so that water quality parameters remain stable [5]. One of the main components in floc formation is phytoplankton, with diatoms being a common type of phytoplankton found within the flocs.

Diatoms are phytoplankton with cell walls composed of silica, thus requiring silica for their growth, particularly for cell wall formation. Silica is essential for diatom cell wall formation and depends on the availability of dissolved silica in the water [6]. Diatoms uptake silica in its dissolved form, as Si(OH)4. The growth of diatoms is influenced by the addition of silica, with a reported impact of 97.02% [7]. During the adaptation phase, the highest density of Thalassiosira sp. occurred with the addition of 20 ppm silica, reaching 262,500 cells/ml [8]. Different types of diatoms require varying amounts of silica [9]. Changes in silica content are one of the factors causing diatom succession [10]. Therefore, the proper addition of silica content influences diatom succession.

This research is a novel study aimed at specifically understanding the impact of silica addition on floc volume density in the biofloc system for red tilapia fry. A better understanding of how silica affects floc volume density can provide important insights for optimizing biofloc management, enhancing aquaculture productivity, and supporting more sustainable aquaculture practices.

2. MATERIALS AND METHODS

2.1 Research Area

This research will be conducted from January to March 2024 at the Center of Excellence for Higher Education Science and Technology (PUI-PT) Functional Nano Powder, Universitas Padjadjaran, for activities related to the biofloc system, observation of floc volume density and water quality.

2.2 Experimental Setup

The equipment used includes 19 L cylindrical tubes, aeration equipment, a heater, a digital scale (accuracy 0.1 g), a millimeter block (accuracy 0.1 cm), a net, label paper, a microscope, a dropper, and a 1 L measuring cup. The materials used are 3-4 cm red tilapia juvenil, PF1000 feed with 39% protein content, molasses, EM4, coarse salt, dolomite lime, and nanosilica.

2.3 Biofloc Media Preparation

To form the biofloc system in a 19 L water volume medium, the materials used per cylindrical tube are 1.5 grams of salt (100 g/m^3), 0.75 grams of dolomite lime (50 g/m^3), 0.6 ml of molasses, and 1 ml/L of EM4. These materials are dissolved in a measuring cup and then added to the biofloc medium, which is the cylindrical tube.

2.4 Implementation of Research

The biofloc maintenance activities are conducted for 45 days. Silica is added to each treatment every 7 days. Observations of floc volume density are carried out every 7 days, water quality observations, including temperature and pH, are conducted daily, while observations of nitrite, nitrate, and ammonia levels are performed every 7 days.

2.5 Research Methods

The research method used is the experimental method with a Completely Randomized Design (CRD), consisting of 4 treatments and 3 replications, as follows:

Treatment A: Addition of 0 ppm silica concentration (control)

Treatment B: Addition of 15 ppm silica concentration

Treatment C: Addition of 20 ppm silica concentration

Treatment D: Addition of 25 ppm silica concentration

2.6 Research Parameters

2.6.1 Floc volume density

The floc volume density is measured using a 1 L measuring cup. Every 7 days, a 1 L water sample is taken from each treatment and replication, and then placed in the measuring cup. The water sample is left to settle for 20 minutes, after which the volume of the sedimented solids (floc) at the bottom of the measuring cup is measured. The floc density is recorded in ml/L.

$$\text{Floc volume} \left(\frac{ml}{L}\right) = \frac{V\ sediment}{V\ water\ sample} \times 1000$$

2.6.2 Water quality

Here are several parameters of water quality observed in this study (Table 1).

Table 1. Water quality parameters

Parameters	Unit	Measurement Time	Standard
Temperature	°c	Per day	25-30°C [11]
pH	-	Per day	6,5-8,5 [12]
DO	mg/L	Per week	> 5 mg/L [12]
Nitrite	mg/L	Per week	<0,06 mg/L [13]
Nitrate	mg/L	Per week	3,9-15,5 mg/L [13]
Ammonia	mg/L	Per week	0,02 mg/L [12]

3. RESULTS AND DISCUSSION

3.1 Floc Volume Density

Floc volume is one way to observe the abundance of biofloc-forming organisms. Floc-forming bacteria decompose organic matter (protein, carbohydrates, fats, etc.) derived from leftover feed, fish waste, and dead organisms in the pond [14]. Floc volume is the amount of suspended solids over a certain period in an inverted cone container [15]. A high floc volume value in biofloc treatments indicates that the bacteria in the maintenance pond can form flocs, which can then be utilized by the fish as additional feed for growth and reduce the amount of feed provided. The density of bioflocs in the maintenance media can be measured using a floc volume measuring device, which is conical with a volume scale at the bottom and made of glass or transparent plastic [14].

Based on the observations of floc volume during the maintenance period, it was found that the addition of silica had an effect on floc volume. The differences in floc volume observed throughout the study were quite fluctuating. Looking at the final observation in the 6th week, the lowest floc volume was found in treatment A (0 ppm) with a value of 17 ml/L, while the highest floc volume was observed in treatment D (25 ppm) with a value of 26.5 ml/L, followed by treatment C (20 ppm) with a value of 25 ml/L, and treatment B (15 ppm) with a value of 22.5 ml/L (Fig. 1).

Based on Fig. 1, treatments with added silica showed higher floc density compared to the control treatment. This is attributed to an increased presence of diatoms within the flocs, influenced by silica's role in enhancing their growth and cell wall formation. Silica is an essential macro-nutrient crucial for diatoms to develop robust cell walls that can withstand environmental stresses, including extreme conditions [16]. As more flocs form, the overall floc volume tends to increase [17].

Based on its volume, biofloc is classified as dense when the floc volume in water reaches >20 ml/L, moderate if it reaches 10–20 ml/L, low if it reaches 1–10 ml/L, and very low if it is <1 ml/L [18]. In the treatments with added silica (Treatments B, C, and D), they fall into the dense category as their floc volumes exceed 20 ml/L, while Treatment A falls into the moderate category.

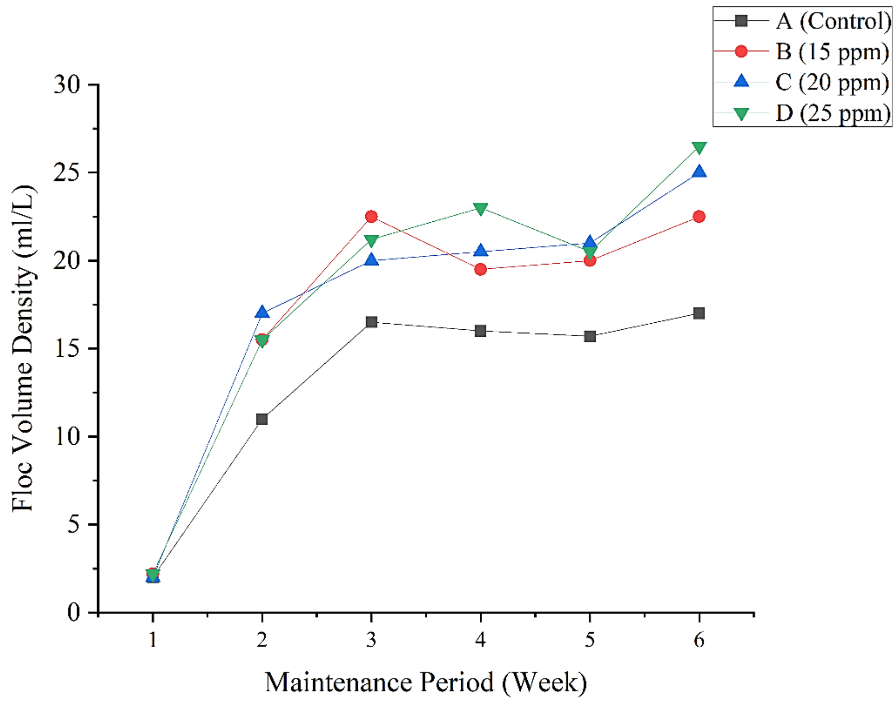

Fig. 1. Biofloc system floc volume density

Compared with research in 2023 on polyculture biofloc systems of catfish and tilapia, where the highest floc volume reached 4.37 ml/L, the silica addition study achieved higher results [19]. However, it is lower compared to research in 2023 on tilapia biofloc cultivation, where the floc volume reached 33 ml/L [20].

The increase in floc volume indicates optimal activity of floc-forming bacteria, likely due to the accumulation of ammonia and phosphorus in the culture media beforehand. In aquaculture, biofloc systems emphasize the growth of bacteria in the media to replace autotrophic communities dominated by phytoplankton [5].

Additionally, according to [21], the fluctuation patterns observed in floc volume are strongly influenced by parameters such as temperature, dissolved oxygen (DO), pH, ammonia, nitrite, and nitrate. These factors are related to the breakdown processes of leftover feed and metabolic waste, which occur within the culture media.

3.2 Water Quality

Water quality is crucial to aquaculture activities as it significantly impacts the development and growth of fish. Good water quality is characterized by meeting standard criteria for water quality parameters. In this study, water quality parameters measured include temperature, pH, Dissolved Oxygen (DO), nitrate, nitrite, and ammonia. The measurement of water quality was observed from the beginning to the end of the fish maintenance period (Table 2).

Temperature observations during the research, as shown in Table 2, indicate a stable temperature range within the optimal growth conditions for Biofloc, around 24°C. Temperature influences cellular metabolism, primarily affecting enzyme activity [22]. Low temperatures slow down enzyme activity, while excessively high temperatures can damage enzymes, halting cellular metabolism. The optimal temperature range for Biofloc growth is typically between 20°C to 30°C [23]. Temperature also affects the rate of decomposition and conversion of organic matter into inorganic substances. In this study, temperatures ranged from 25°C to 27°C, which are favorable for phytoplankton life in general, where temperatures for optimal phytoplankton life generally range from 20°C to 30°C [15].

In the pH observations, a range of 6.5-7.52 was recorded. pH (acidity level) is a crucial chemical parameter in water quality assessment. Optimal Biofloc growth is achieved by adjusting pH appropriately. This adjustment is important because pH levels in the medium can influence enzyme activity during cellular metabolism. pH levels also affect the photosynthetic rates of microalgae and the overall performance of enzymes in metabolic processes [24]. Acidity levels significantly impact aquatic plants and animals, often serving as an indicator of water quality for aquatic organisms. pH values are heavily influenced by photosynthesis activity and temperature. The ideal pH range for organisms, including phytoplankton, generally falls between 6.5 to 8.5 [25]. Specifically for tilapia hatcheries, the optimal pH range is recommended to be between 6.5 to 8.5 [12].

The dissolved oxygen (DO) levels observed during the study ranged from 6.13 to 7.20 mg/L, indicating optimal DO values within the normal condition of >3 mg/L [12]. Biofloc cultivation is closely associated with strong aeration to maintain adequate oxygen levels in the culture medium. It's further noted that bacteria utilized in biofloc systems also require oxygen for metabolizing leftover feeds and metabolic wastes. In general tilapia culture, DO levels around 3 mg/L are sufficient for tilapia survival; however, in biofloc systems, a minimum DO level above 5 mg/L is recommended to ensure efficient nitrogen breakdown by heterotrophic bacteria [26]. Low dissolved oxygen levels can inhibit bacterial activity and lead to increased ammonia levels in the water.

Table 2. Biofloc system maintenance water quality

Treatments	Temperature (ºC)	pH	DO (mg/L)	Nitrate (ppm)	Nitrite (ppm)	TAN (ppm)	NH3 (mg/L)
A	25-27	6,51-7,49	6,18-7,20	0,0-5,0	0,0-0,5	0,3-4,0	0,0006-0,821
B	25-27	6,50-7,49	6,32-7,49	0,0-5,0	0,0-0,3	0,3-4,0	0,0005-0,0821
C	25-27	6,74-7,52	6,15-7,00	0,0-5,0	0,0-0,3	0,3-2,3	0,001-0,0505
D	25-27	6,72-6,67	6,13-6,44	0,0-5,0	0,0-0,3	0,3-1,7	0,0009-0,0484

The levels of nitrite and nitrate during the cultivation period remained relatively low. Nitrite levels throughout the study remained within optimal limits for tilapia farming, specifically below 0.05 ppm. Who defines the threshold for nitrite at 0.05 ppm [27]. Recommend that nitrite concentrations in biofloc technology should ideally be kept below 2 mg/L [28]. Nitrate levels during the study also remained within normal limits for cultivation. Nitrate concentrations in biofloc systems should not exceed 10.0 mg/L [28].

Based on the observation, Total Ammonia Nitrogen (TAN) ranged from 0.3 to 4.0, and ammonia levels ranged from 0.0006 to 0.821. In a biofloc system, it is recommended that ammonia concentrations remain below 1.5 mg/L. Therefore, the ammonia concentration in the biofloc culture medium, ranging from 0.0006 to 0.0821, falls within a safe range for biofloc systems [28].

4. CONCLUSION

The addition of silica in biofloc systems can influence the abundance of diatoms. Diatoms, which are part of phytoplankton, can affect floc volume density. Adding a concentration of 25 ppm silica to the biofloc media during maintenance is the most effective treatment for increasing floc volume density. This is evidenced by observations in the last week, where treatment D (25 ppm) showed a floc volume density of 26.5 ml/L, classified as dense.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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