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The Effect of the Aeration System on Fish Health Performance in Aquaponics

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ABSTRACT

Dissolved oxygen in aquaculture systems, including aquaponics systems, cannot be filled only by natural diffusion, so an artificial aeration system is needed. Suboptimal aeration levels not only affect metabolic activity, but also affect serum and fish blood performance (hematology). This study aims to evaluate the impact of the aeration system on the health and well-being of fish cultivated in an aquaponics system. The method used is by studying the literature related to the aeration system of fish farming carried out in the aquaponic system which is relevant to the keywords of aquaponic system, aeration system, fish health and hematology from various sources such as: Google Scholar, Elsevier, Springer and Research Gate. Based on the comparison of several studies, it can be concluded that the aquaponic system using an aeration system can improve fish health performance based on hematological parameters.

INTRODUCTION

One of the main challenges faced by fish farmers is the limited availability of land for intensive aquaculture. As intensive fish farming continues to expand, it is crucial to consider land and water resource availability. However, rapid development has led to the conversion of aquaculture land, reducing its total area and contributing to a decline in water quality. This, in turn, negatively impacts fish health and poses financial risks for farmers. Therefore, technological advancements and innovative solutions are necessary to sustain aquaculture activities. One effective approach to addressing this issue is the implementation of a Recirculating Aquaculture System (RAS), which can reduce water usage by up to 90% while minimizing waste discharge into the environment.

One innovative approach that can be applied is intensive fish farming integrated with plant cultivation through an aquaponic system. Aquaponic technology combines plant cultivation and fish farming within a single system (Hao *et al*., 2020). The incorporation of plants aims to enhance water quality through phytoremediation. This system is highly water-efficient, reducing water usage in aquaculture by up to 97%, and is environmentally friendly as it produces no waste (Zidni, 2013). Nutrient-rich water from the fish cultivation unit is channeled to the plants, where it is utilized as fertilizer (Zidni, 2013).

One crucial factor to consider in an aquaponic system is the stocking density of the fish, as improper increases in stocking density can have adverse effects, particularly a decline in water quality. This deterioration can lead to fish health issues, ultimately causing financial losses for fish farmers. In aquaculture systems, including aquaponics, dissolved oxygen cannot be maintained solely through natural diffusion, making artificial aeration essential. Aeration plays a significant role in fish growth and metabolic activity (Pawar *et al*., 2014). At an optimal aeration level, metabolism functions at its peak efficiency. Conversely, insufficient aeration results in inadequate oxygen supply, while excessive aeration (overly strong aeration) is inefficient and forces fish to expend excessive energy to maintain their body position. Suboptimal aeration levels not only affect metabolic activity but also influence fish serum and blood performance (hematology). Hematological parameters such as hemoglobin levels, erythrocyte count, hematocrit, and plasma glucose concentration serve as physiological indicators of fish health. These variables can also be used to determine whether fish are experiencing stress or, alternatively, if they are in optimal condition for growth (Kandeepan, 2014). The objective of this study is to evaluate the effects of aeration systems on fish health performance in an aquaponic system.

METHODS

This literature review research was conducted from October to December 2024 in Jatinangor, Universitas Padjadjaran. The method used in this study is a literature review focusing on aeration systems in fish farming within aquaponic systems, a literature review is a section of a research paper or academic work that examines, analyzes, and synthesizes various sources relevant to a specific topic. Tools and materials used in this literature study research (literature review) include laptops, laptop chargers, mice, scientific articles in soft file form. The review is conducted by analyzing relevant studies using keywords such as aquaponic systems, aeration systems, fish health, and hematology. Sources for this study include Google Scholar, Elsevier, Springer, and ResearchGate.

RESULTS

Aeration System

One important factor to consider in an aquaponic system is the stocking density of the fish. Stocking density is a crucial aspect of aquaculture as it influences growth rates, feed conversion ratios, and survival rates, all of which impact production levels (Karlyssa *et al*., 2014). High stocking density can lead to increased fish production, but with lower weight gain per fish. On the other hand, lower stocking density results in reduced total fish production, but with higher individual fish weight (Prastari & Harefa, 2020). The aeration system can be seen in Table 1.

Table 1. Aeration System

Aeration System	Reference
The effectiveness of aeration depends on the surface area of water in direct contact with the air	(Hartini, 2012)
Several types of aerators are commonly used, including gravity aerators, spray aerators, diffuser aerators, and mechanical aerators	(Benefield *et al*., 1982)

Aeration System	Reference
Diffuser aerator type is based on ease of maintenance, high oxygen transfer efficiency, and cost-effectiveness	(Haryanto *et al*., 2005)

Fish Hematology

Hematological studies are conducted on fish to detect physiological changes caused by environmental stress and to assess the overall health status of the fish (Al-Attar, 2005). The fish hematology can be seen in Table 2.

Table 2. Fish Hematology

Fish Hematology	Reference
Hematological parameter values can vary among fish species	(Lukistyowati *et al*., 2007)
The normal erythrocyte count in fish generally ranges from 20,000 to 3,000,000 cells/mm³	(Hartika *et al*., 2014)
Low erythrocyte levels indicate anemia in fish	(Yanuhar *et al*., 2021)
The white blood cell count in fish is generally lower than that of red blood cells, typically ranging from 20,000 to 150,000 cells/mm³	(Zubaidah *et al*., 2019)
Low hemoglobin levels result in a decrease in the oxygen content in the blood	(Ulfa, 2015)
The continuous functioning of the brain requires a constant supply of glucose	(Hastuti *et al*., 2003)
The normal blood glucose level in fish typically ranges from 40 to 90 mg/dL	(Nasichah *et al*., 2016)

The Effect of Aeration System on Fish Health

Aeration is essential as the primary source of oxygen for the fish. Several studies on the impact of aeration systems on fish health performance are summarized in Table 3.

Table 3. The Effect of Aeration System on Fish Health

Types of Aeration	The Effect of Aeration System on Fish Health	Reference
Blower Aeration	Hemoglobin levels ranging from 7.40–7.78 g/100 mL, blood glucose levels from 63.00–70.25 mg/100 mL, and hematocrit levels of 42.51% and 43.53%, respectively	(Dewantoro, 2019)
Air Pump Aeration	Reduce ammonia levels and minimize damage to the gill tissue of red tilapia	(Djaelani, 2023)
Microbubble	Increases dissolved oxygen by 12% higher compared to blower aeration. Glucose and cortisol levels increase with higher stocking densities	(Heriyati, 2022)
Fine Bubble (FBs)	Provide dissolved oxygen above the needs of Siamese catfish, reduce ammonia levels to 0.0358 ppm hour-1 L-1, and inhibit the growth of *Aeromonas hydrophila* bacteria.	(Subhan *et al*., 2018)

DISCUSSION

The aquaponic system is a sustainable integration of aquaculture and hydroponics, where fish waste, including metabolic byproducts and uneaten feed, serves as a natural fertilizer for plant growth (Stathopoulo *et al*., 2018). The primary principles of aquaponics are to optimize land and water use, enhance operational efficiency by repurposing fish metabolic waste as plant nutrients, and promote environmentally friendly farming practices (Zidni *et al*., 2019). In an aquaponic system, plants serve as biological filters, directly absorbing nutrients from fish waste to support their growth. As a result, the filtered water becomes cleaner, creating a healthier environment for the fish (Andriani & Zahidah, 2019).

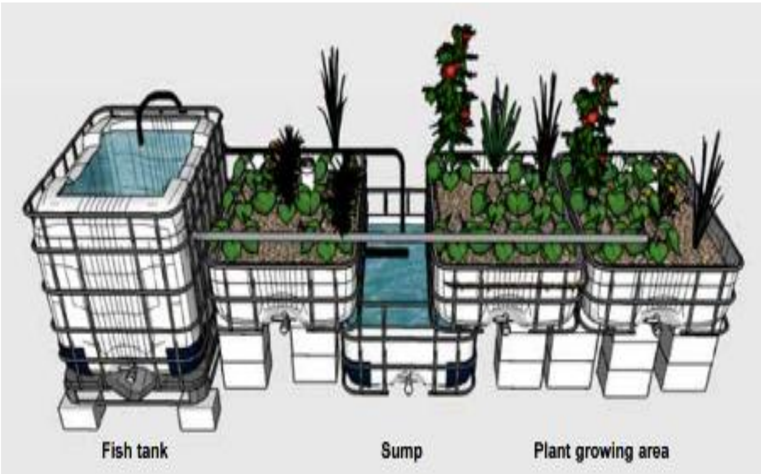

Figure 1. Aquaponic (Somerville *et al*., 2014)

According to Gumelar *et al*. (2017), the working mechanism of an aquaponic system involves the conversion of organic waste, such as fish feces and urine, into ammonia. However, at high concentrations, ammonia can be toxic to fish. In an aquaponic system, ammonia-rich organic waste is utilized by decomposer bacteria that inhabit the culture tank walls, growing media, filter media, and other surfaces as a nutrient source. Aerobic bacteria convert ammonia into nitrites, which are then transformed into nitrates by anaerobic bacteria. Nitrates, commonly recognized as macronutrients, are absorbed by plants to support their growth. In return, plants contribute oxygen to the system, improving water quality for both fish and decomposer bacteria. This process occurs continuously within the system, ensuring a balanced and sustainable environment.

The design of an aquaponic system can be tailored to suit the available land, as well as the species of fish and plants being cultivated (Somerville *et al*., 2014). Several aquaponic system designs are commonly used, including the Nutrient Film Technique (NFT), media bed, and Deep-Water Culture (DWC). Common plants cultivated in aquaponic systems include water spinach, lettuce, and pakcoy (Zidni *et al*., 2013). These plants also serve as phytoremediators, capable of reducing, extracting, or eliminating both organic and inorganic compounds from waste (Hadiyanto & Christwardana, 2012). In addition to their role as waste phytoremediators, plants in aquaponic systems also hold economic value, as they can be harvested and consumed.

Aeration System

Excessive stocking density presents a significant challenge in fish farming, as it can lead to reduced growth rates and survival rates of the fish (Suryadijaya & Saragih, 2023). High stocking density can also result in a decrease in dissolved oxygen levels, while ammonia

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concentrations increase. Poor water quality in an aquaponic system can cause fish diseases and fatalities, which in turn negatively impact fish production. In aquaponic systems with high stocking density, dissolved oxygen cannot be sufficiently provided through natural diffusion alone, as the ability of plants to absorb ammonia decreases with higher ammonia concentrations. Therefore, artificial aeration is necessary in aquaponic systems.

Aeration is the process of adding oxygen to water, thereby increasing the dissolved oxygen levels. Essentially, aeration involves mixing water with air or other materials to allow low-oxygen water to come into contact with oxygen or air. The aeration process is the dissolution of oxygen into the water (Hartini, 2012). The primary function of aeration is to dissolve oxygen into water, increasing the dissolved oxygen content, releasing dissolved gases, and assisting with water agitation. Aeration can also be used to remove dissolved gases, oxidize iron and manganese in the water, and reduce ammonia levels through the nitrification process. According to Benefield *et al*. (1982) as cited in Batara (2017), several types of aerators are commonly used, in aquaponic systems, the most commonly used aerator is the diffuser aerator.

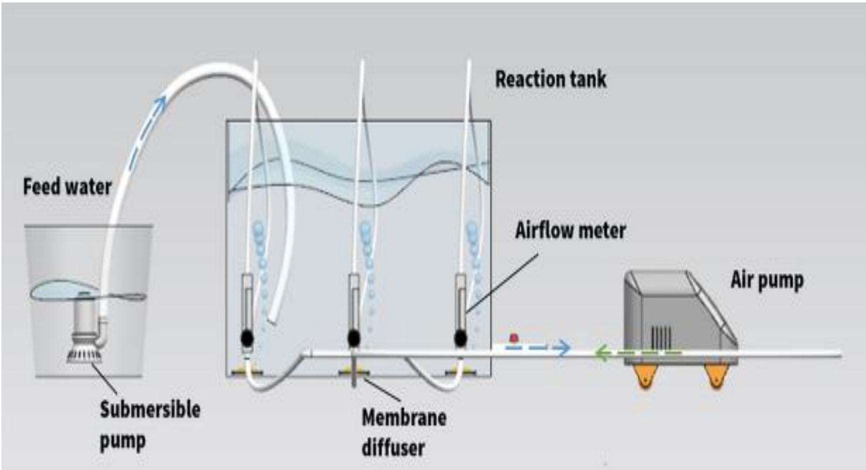

Figure 2. Diffuser Aerator (Wang *et al*., 2020)

The diffuser aerator type facilitates the transfer of oxygen from pressurized air injected into the water. The air injection occurs in large tanks through porous diffuser plates or tubes. The air released from the diffuser typically forms bubbles, which increase water turbulence.

Fish Hematology

Observing the hematological condition of farmed fish serves as a non-specific defense mechanism and can help identify health conditions, providing early detection for disease diagnosis. This allows for timely treatment and disease prevention efforts. Hematological parameter values can vary among fish species depending on factors such as species, age, size, gender, environmental conditions, and exposure to pathogenic microorganisms (Lukistyowati *et al*., 2007). Hematological parameters that can be assessed include red blood cell (erythrocyte) count, white blood cell (leukocyte) count, hemoglobin levels, and blood glucose levels in fish.

1. Red Blood Cells

   Red blood cells (erythrocytes) are the most abundant type of cells in the blood. Erythrocytes contain a large amount of carbonic acid, which plays a crucial role in catalyzing the reaction between carbon dioxide and water, enabling the blood to transport carbon dioxide from tissues to the gills (Lusiastuti & Handayani, 2018). Yanuhar *et al*. (2021) note that low erythrocyte levels indicate anemia in fish, while abnormally high erythrocyte counts suggest that the fish is under stress. A low erythrocyte count can prevent the fish from obtaining sufficient oxygen, leading to anoxia or oxygen deficiency.

2. White Blood Cells
   White blood cells (leukocytes) in fish are part of the non-specific immune system. Leukocytes play a crucial role in producing antibodies, which are essential for the organism's cellular and humoral defense against foreign substances. They also act as a defense mechanism by penetrating tissues without causing damage. According to Zubaidah *et al*. (2019), the white blood cell count in fish is generally lower than that of red blood cells.
3. Hemoglobin
   Hemoglobin (Hb) is a component of red blood cells that plays a vital role in the circulatory system. Hemoglobin is essential for transporting gases, particularly oxygen, from the gills, pumped by the heart, to the body's cells and organs. It also helps transport nutrients into cells and eliminate metabolic waste, among other functions. Hemoglobin carries oxygen by binding to iron (Fe) in the blood (Ulfa, 2015).
4. Blood Glucose
   Blood glucose in fish serves as the primary energy source and provides essential fuel and substrates for cellular metabolism, particularly in brain cells (Hastuti *et al*., 2003). Measuring blood glucose levels is a simple and effective method for diagnosing stress in fish caused by various stressors (Sulmartiwi *et al*., 2013). The normal blood glucose level in fish typically ranges from 40 to 90 mg/dL (Nasichah *et al*., 2016).

The Effect of Aeration System on Fish Health

In intensive aquaculture, the demand for oxygen is very high, and its supply cannot be met solely through direct diffusion from the air. The research results indicate that the hematological performance of Tengadak fish tends to improve (indicating better health) with increasing levels of aeration, up to the aeration level of 10 L/min/40 L (Dewantoro, 2019). The addition of aeration combined with filtration can reduce ammonia levels and minimize damage to the gill tissue of red tilapia (Djaelani, 2023).

The research results show that microbubble aeration increases dissolved oxygen by 12% higher compared to blower aeration and can enhance the carrying capacity of aquaculture, water quality, growth, health, and immunity of red tilapia. Glucose and cortisol levels increase with higher stocking densities, but the differences are not statistically significant (Heriyati, 2022). The use of FBs can provide dissolved oxygen above the needs of Siamese catfish, reduce ammonia levels to 0.0358 ppm hour-1 L-1 (Subhan *et al*., 2018).

Fish hematological performance is influenced by internal factors such as age, sex, and hormonal conditions (Baghizadeh & Khara, 2015), as well as external factors like diseases, feed, and water quality (Chapman, 2015). At optimal aeration levels, metabolism will occur maximally. Conversely, when aeration is too low, the required oxygen will be insufficient, while excessive aeration (too strong) becomes inefficient in oxygen usage and forces the fish to expend too much energy to maintain body position. Suboptimal aeration levels not only affect metabolic activity but also impact the fish's serum and blood performance (hematology).

CONCLUSION

Effective aeration is vital for the sustainability and productivity of aquaponics systems. By selecting appropriate aeration techniques and monitoring dissolved oxygen levels, aquaponics practitioners can ensure a balanced ecosystem that supports fish, plants, and beneficial bacteria. Continuous innovation in aeration methods can further optimize system performance and resource efficiency.

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