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ANALYSIS OF THE PERFORMANCE OF MICROBUBBLE GENERATORS AS AERATORS IN TILAPIA CULTIVATION WITH HIGH DENSITY FISHERY SYSTEMS

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ABSTRACT: Fish farmers in Gresik Regency face significant challenges in developing aquaculture, including land conversion and extended dry seasons that lead to pond drought. Microbubble generators (MBGs) present a potential solution to these issues. This study evaluates the effectiveness of different MBG types in tilapia farming. Weekly measurements of fish mass and length were conducted to determine growth rates using direct methods. Water quality was assessed by testing COD and ammonia levels at the Gresik Regency DLH Laboratory and measuring dissolved oxygen levels directly with a DO meter. The distribution and size of the bubbles were analyzed using the shadow image technique, supported by MATLAB software. The study employed a stocking density of 100 fish/m² with three treatments: MBG swirl type, venturi type, and a conventional aerator. The findings revealed that the MBG swirl type resulted in the best fish growth and maintained water quality within the required standards. The specific growth rate in swirl-type ponds was 3.970 ± 0.014, with a survival rate of 100%. Additionally, the swirl-type MBG effectively maintained dissolved oxygen levels above 3 ppm, meeting the minimum requirement for fish survival, despite having less optimal microbubble distribution compared to the venturi type. While the MBG venturi type performed well initially, technical issues affected its bubble consistency over time. Enhancements in the venturi MBG's design are recommended to improve its performance and reliability.
Keywords: microbubble, microbubble generator, tilapia cultivation, water quality.

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INTRODUCTION

Tilapia is among the most widely farmed fish species in Indonesia. This assertion is substantiated by data from the Ministry of Marine Affairs and Fisheries, which reveals that, in the first quarter of 2022, tilapia led aquaculture production with a staggering output of 358 thousand tons (Perikanan, 2022). Tilapia offers numerous advantages, including ease of maintenance, resilience to diseases, and adaptability to adverse environmental conditions, such as elevated ammonia concentrations, fluctuating pH and dissolved oxygen (DO) levels, and high temperatures. Moreover, tilapia boasts significant economic value (Hertanto, 2013).

As a freshwater species of great national importance, it has garnered substantial governmental attention, particularly in initiatives aimed at improving nutrition in developing countries. Consequently, numerous efforts have been made, and continue to be pursued, to boost tilapia productivity across Indonesia.

To meet the escalating demand, tilapia farming is increasingly being conducted at high stocking densities in limited water volumes (Salsabila, 2018). However, this intensification poses several challenges, particularly with respect to land scarcity and declining water quality, both of which have a direct, negative impact on the productivity of natural resources. The persistent decline in water discharge from public water bodies has become evident, highlighting the need for a strategic approach to sustain food production despite limitations on land and water resources. Thus, it is imperative to implement an intensive aquaculture system to mitigate these challenges and ensure sustainable resource management.

Water quality is a critical determinant of success or failure in aquaculture operations. Optimal conditions for fish growth hinge on a favourable cultivation environment, which is closely tied to the fish's metabolic rate and the availability of oxygen in the water. A decrease in dissolved oxygen (DO) levels negatively affects fish appetite, feed conversion efficiency, growth, and overall health (Boyd, 1998). To address these issues, a technological innovation — the Microbubble Generator (MBG) — has been developed to enhance oxygen solubility. Because of their tiny size, microbubbles offer several benefits for fish farming. They possess a substantial gas-liquid interface, for the same volume, provide a greater transfer area compared to regular bubbles (Parmar and Majumder, 2013). Additionally, their slow rise velocity causes them to dissolve in water rather than bursting at the surface (Li, 2006).

Microbubble aeration technology has emerged as a focal point of research. Microbubbles can be generated through several methods. One approach utilizes a vortex, where air is drawn into the vortex and fragmented into microbubbles through centrifugal force, a technique commonly known as the swirl-type Microbubble Generator (Wu et al., 2022). Additionally, the venturi meter principle represents another approach, wherein the flow velocity increases as it passes through a narrow section, causing a drop in pressure and creating a vacuum. This vacuum draws in air, which is then fragmented into microbubbles by the kinetic energy of the flow. This method is referred to as the venturi-type Microbubble Generator (Juwana et al., 2019).

The innovation of this study lies in the application of MBG technology as an aeration system for tilapia cultivation. Furthermore, the study incorporates the use of smaller land areas for aquaculture. This research evaluates the performance of both the swirl-type and venturi-type MBGs, aiming to determine the most effective aerator configuration for tilapia farming. Moreover, employing MBG technology as an aeration medium in aquaculture represents a novel approach that holds great potential for significantly enhancing fish production.

METHOD

This study consists of three phases: the production of MBG aerators, the measurement of bubble sizes, and the cultivation of tilapia. The fabrication of MBG

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aerators and bubble size measurements were conducted in the Mechanical Engineering Laboratory at the University of Muhammadiyah Gresik, while the tilapia cultivation took place in the Fisheries Laboratory of the same university over a three-month period from May to August while Water quality was assessed by testing COD and ammonia levels at the Gresik Regency DLH Laboratory.

Manufacture of MBG Aerator

MBG aerators were made using SLA LCD 3D printers. The MBG aerators made were swirl and venturi types. The design of the swirl MBG aerator is shown in Figure 1 and the venturi MBG aerator is shown in Figure 2. The resin used in this process was ESUN SLA Standard Resin with a clear type.

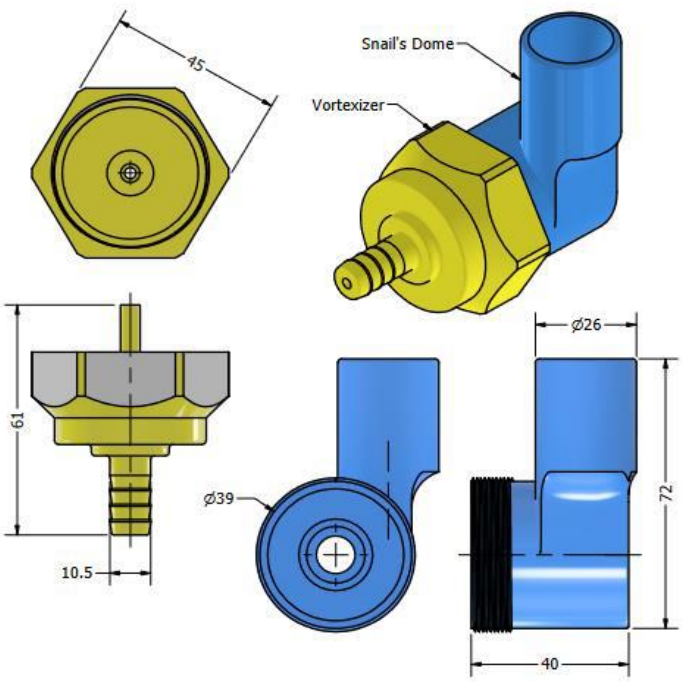

Figure 1. MBG Swirl Type Aerator Design

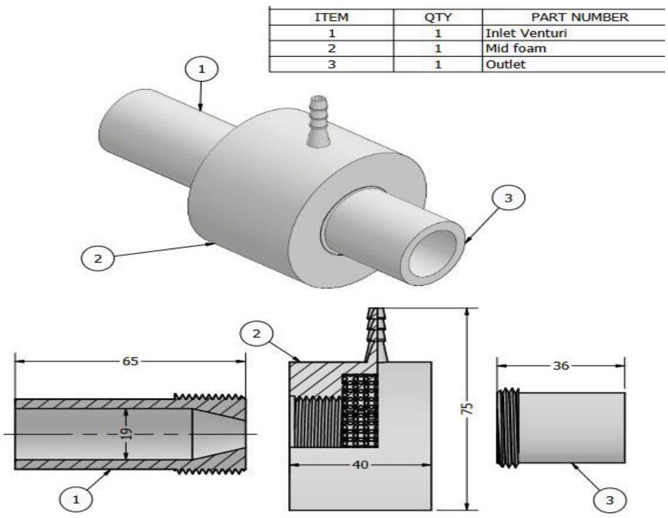

Figure 2. MBG Venturi Type Aerator Design

Tilapia Fish Cultivation Process

This study used 3 concrete pools measuring 1.50 m x 95 m x 80 m with different treatments. The first pool was treated with a Porous-Venturi type MBG aerator, the second pool was treated with a Swirl type MBG aerator and the third pool was treated using 2 conventional aerators. The sterilization process was carried out in all three pools. The sterilization process was carried out by cleaning the pool with a solution of coarse salt, then rinsing and leaving it for 1 day until the three pools dry. After being left for 1 day, the pool was filled with tap water to a height of 75 cm.

The tilapia seeds were acclimatized in the pond for 30 minutes, after which the fish seeds were released into the experimental pond. Each pond was filled with 100 tilapia seeds. The seeds used were seeds with a length of ± 5 cm. During the tilapia cultivation process, each was maintained by siphoning the three experimental ponds periodically. Sampling for water quality was done before siphoning. Water quality was tested at the Gresik Regency Environmental Service. The treatment of feeding in the three ponds was carried out in the morning and evening by ad libitum. The daily fish feed requirements were recorded. Data collection on the mass and length of fish was carried out weekly.

Bubble Diameter Measurement

Measurement of bubble size distribution was carried out using digital image analysis method. The implementation of this method can be divided into two parts, taking pictures with a digital camera and image processing using MATLAB software. Shadow image technique was used to record bubble images. The bubble being photographed was located between the camera, the diffuser screen and the light source. Bubbles reflect light, so that what is captured by the camera is the shadow of the bubble in the form of a dark image.

Data Analysis

To assess the fish's growth potential, calculations were performed for several key parameters. The performance of MBG in fish growth was evaluated by food conversion ratio (FCR), specific growth rate (SGR), daily weight gain (DWG), and Survival Rate (SR) (Ronald et al, 2014).

$$SGR\ (\%\ per\ day) = \frac{\ln(W_f)-\ln(W_s)}{t} X100\% \quad (1)$$

$$DWG = \frac{W_f - W_s}{t} \quad (2)$$

$$FCR = \frac{W_f\, N_t - W_s\, N_0}{W_p} \quad (3)$$

$$SR = \frac{N_t}{N_0} X100\% \quad (4)$$

Where Wf is the final weight of the fish, Ws is the initial weight of the fish, t is the rearing time and Wp is the weight of the feed given to the fish.

Image analysis was performed using MATLAB software. First, the image was cropped to remove unwanted areas to obtain an image with uniform color. This process can also reduce the image processing load because the image size has been reduced. Furthermore, the image filtering process was carried out by significantly

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increasing the color contrast between the object and the background. Then, the filtered image was converted into a binary image. Binary images consist of 2 types of images, images with solitary bubbles and images with overlapping bubbles. Overlapping bubble images will cause problems in measuring the diameter so they need to be converted first into solitary images using the watershed method. All solitary images obtained were then analyzed quantitatively, including the area, equivalent diameter, center, perimeter and roundness of the bubbles (Juwana, 2018).

RESULTS AND DISCUSSION

The growth of tilapia is quantitatively assessed through the increase in both mass and length. Fish growth data is collected on a weekly basis. The results of the mass measurements are presented in Figure 3.

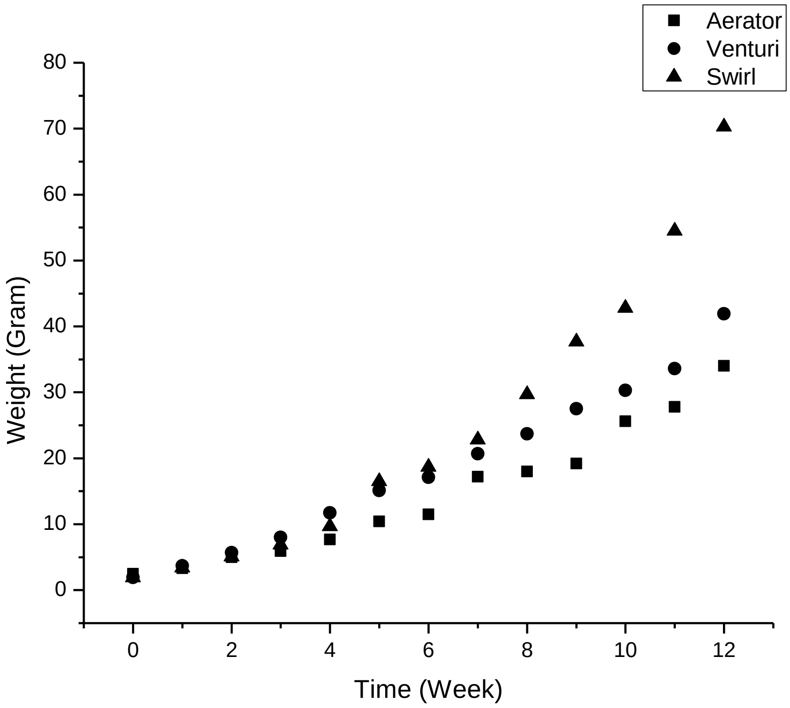

Figure 3. Fish Weight on Various Types of Aerators

Figure 3 shows that using MBG aerators significantly improves fish growth. In the first three weeks, fish growth was relatively similar across all treatments. This consistency aligns with findings by Lakani et al. (2013), who explain that fish oxygen demand increases with body mass. At the early growth stage, fish display comparable growth patterns under hypoxic, normoxic, and hyperoxic conditions. However, by the fifth week, a notable difference emerged, with MBG use demonstrating a significant advantage. Heriyati et al. (2022) found that MBG enhances the tilapia's resilience to stress, resulting in greater growth stability. Over time, though, the venturi-type MBG showed reduced effectiveness. Fish waste was drawn into the air chamber cavity, obstructing microbubble formation and

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hindering fish growth. Additionally, design limitations of the venturi MBG complicated cleaning and maintenance.

In contrast, the swirl-type MBG proved more suitable for high-density tilapia cultivation. As noted by Mawarni et al. (2022), the swirl MBG produces smaller bubbles than the venturi type. Its simpler construction reduces the risk of environmental failures and makes maintenance easier, making it a better choice for such systems. To corroborate these findings, fish length measurements were conducted, and the results are presented in Figure 4.

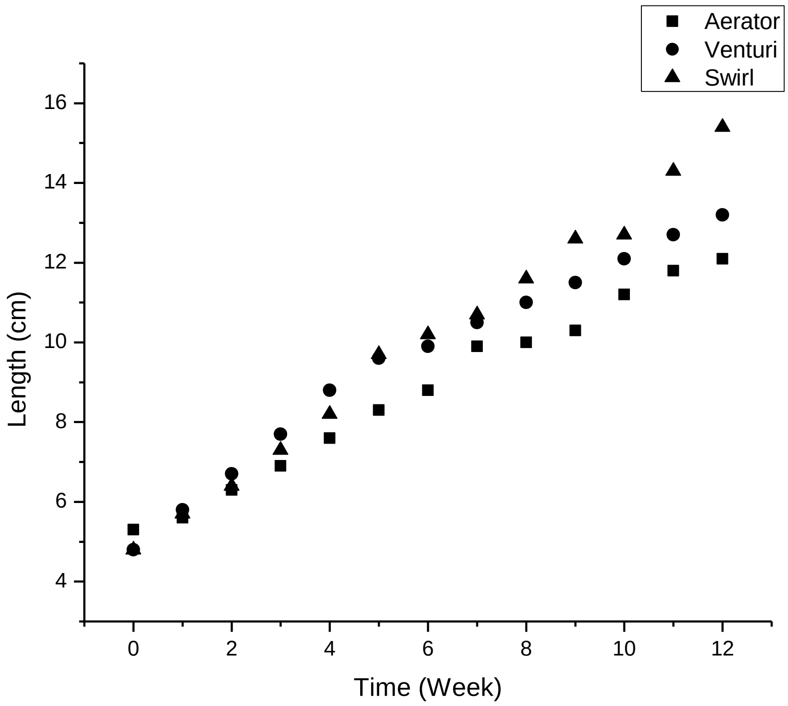

Figure 4. Fish Length in Different Types of Aerators

The relationship between fish length and weight is directly proportional, with increased weight correlating to greater length. However, the implementation of high-density stocking can lead to deleterious conditions for the fish, resulting in stunted growth (Diansari et al., 2013). Furthermore, high-density environments can adversely affect the physiological and behavioral aspects of fish due to constrained space for movement, ultimately diminishing overall fish productivity (Azhari et al., 2017). Boyd (1998) explains that low dissolved oxygen (DO) levels and high nitrite concentrations in the culture environment can trigger the formation of methemoglobin, impairing oxygen transport in the bloodstream. This condition increases stress and can be fatal. Oxygen levels below 2 mg/L can be lethal if sustained for hours, while optimal tilapia cultivation requires DO levels above 5 mg/L; intermediate levels may slow growth rates.

A decline in DO levels also affects feeding activity, with fish ceasing to feed entirely at oxygen levels below 1 ppm. Although excessive DO levels rarely cause immediate mortality, they can result in gas embolism, where oxygen bubbles block

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capillaries in the gill filaments (Susanto, 2000). The use of microbubbles helps address these challenges. Due to their small size, microbubbles maintain high oxygen concentrations in the water, reducing the risk of hypoxia and its associated complications.

To evaluate fish growth rates, several key parameters were calculated, including Specific Growth Rate (SGR), Daily Weight Gain (DWG), Feed Conversion Ratio (FCR), and Survival Rate (SR). The results of these calculations are presented in Table 1.

Table 1. Calculation Results of Tilapia Growth Parameters

Parameters	SGR	DWG	FCR	SR
Aerator	2.885 ± 0.080	0.213 ± 0.133	0.884 ± 0.340	93
Swirl	3.970 ± 0.014	0.978 ± 0.226	2.079 ± 0.481	100
Venturi	3.392 ± 0.170	0.586 ± 0.146	1.363 ± 0.340	97

Table 1 substantiates Mallya's (2007) assertion that maintaining optimal levels of dissolved oxygen (DO) is crucial for sustaining the digestive metabolism of fish, thereby enhancing the efficiency of feed conversion into fish biomass. The daily biomass yield achieved in the MBG tank is sufficiently high to facilitate the implementation of a high-density aquaculture system, supported by the utilization of a swirl-type MBG aerator.

Water Quality

Chemical Oxygen Demand (COD) testing was conducted using water samples from tilapia ponds, all collected from the same sampling location and at the same time to ensure consistency. The results of the COD analyses are illustrated in Figure 5.

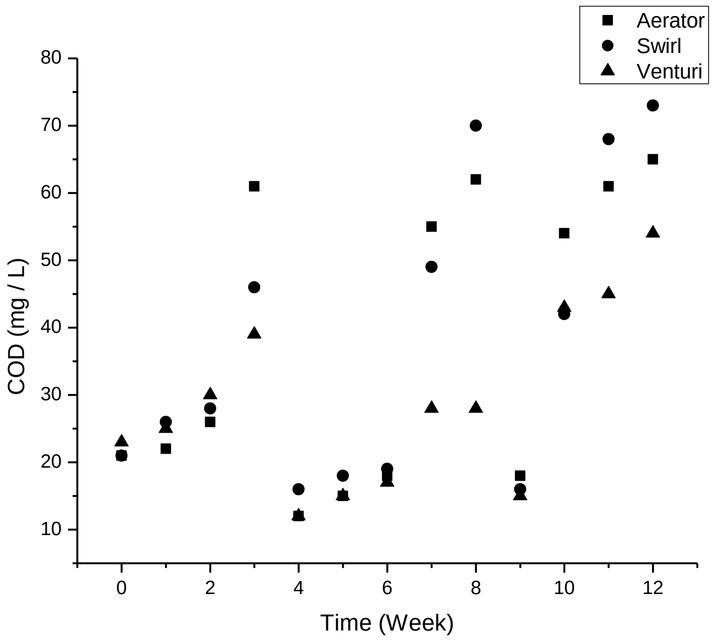

Figure 5. COD Values on Various Types of Aerators

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The Chemical Oxygen Demand (COD) gradually increases throughout the cultivation process. In the first month, it takes about four weeks for the COD levels to exceed the acceptable limit, which is set at 40 mg/L according to Dampin et al. (2012). Over time, the rate of COD increase accelerates due to the growing fish biomass, leading to higher fecal output. By the tenth week onward, COD levels consistently surpass the permissible threshold, requiring more frequent siphoning. During the first two months, siphoning was conducted monthly. By the eighth week, the frequency was increased to once every two weeks, and in the final two weeks, siphoning was performed weekly to effectively control the rising COD levels.

In addition to COD testing, assessments of total ammonia concentration were also conducted, as total ammonia is a critical parameter in tilapia cultivation. The results of these tests are presented in Figure 6.

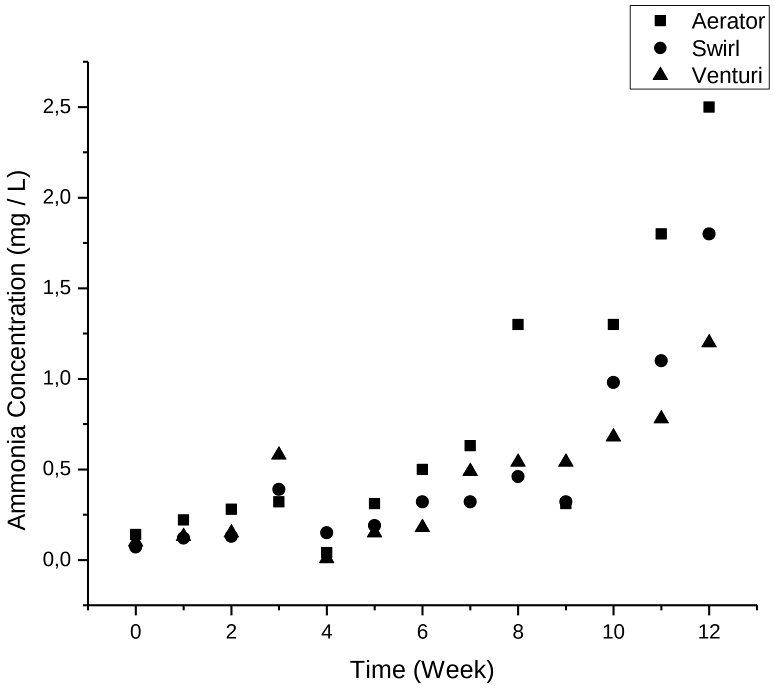

Figure 6. Ammonia Concentration in Several Types of Aerators

According to Wahyuningsih and Gitarama (2020), the permissible limit for ammonia concentration in water is 1.5 mg.L^{-1}. The ammonia concentration exceeded this threshold during the eleventh week of the study. The data indicates that the Microbubble Generator (MBG) effectively enhances water quality compared to conventional aerators. Specifically, the ammonia levels in ponds utilizing MBG aerators were lower than those in ponds employing traditional aeration methods.

To assess the dissolved oxygen conditions in this study, measurements of dissolved oxygen levels in the water were conducted. The results of these measurements are detailed in Table 2.

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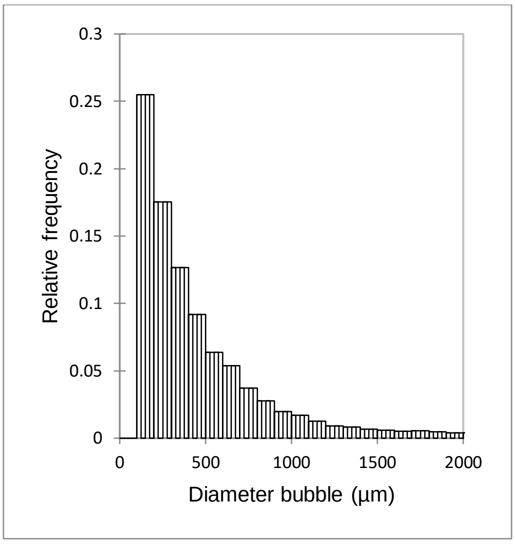
Table 2. Dissolved Oxygen Measured in Cultivation Ponds

Week		2	4	6	8	10	12
Aerator	Morning	4.05	3.25	3.27	2.87	2.38	1.87
	Evening	3.93	2.87	3.31	2.91	1.97	2
Swirl	Morning	1.08	4.69	4.72	3.52	3.96	4.46
	Evening	1.42	4.25	4.94	3.7	3.33	3.32
Venturi	Morning	1.71	4.33	4.43	3.8	3.8	2.7
	Evening	2.43	3.77	5.06	4.09	3.31	2.04

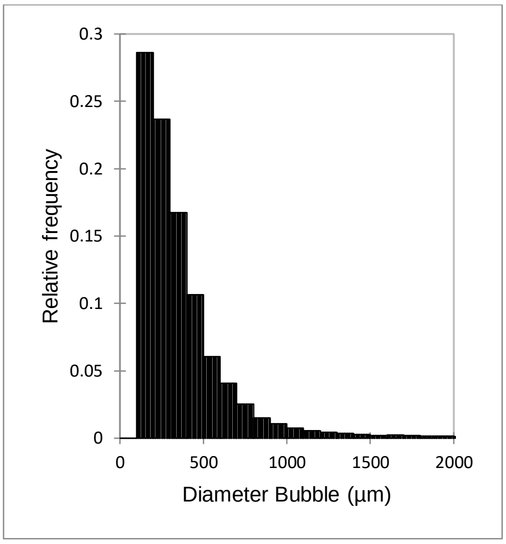
Table 2 demonstrates that the oxygen requirements of fish increase in accordance with their mass. Additionally, the Microbubble Generator (MBG) effectively maintains elevated dissolved oxygen levels in the water, thereby enhancing its efficacy. Another notable observation is that, generally, the concentration of dissolved oxygen in the water is higher during the day. This phenomenon occurs because the algae present in the photosynthetic tank produce oxygen through photosynthesis, leading to increased dissolved oxygen concentrations during daylight hours.

Bubble Diameter

A comprehensive analysis was performed to examine the distribution pattern of the generated bubble population. The findings are presented as a probability density function (PDF) to enhance the visualization of the relative frequency of bubble distribution. The analysis focused on a range of 100 µm, with the results illustrated in Figure 7.



(a)



(b)

Figure 7. Bubble Population Distribution in (a) MBG Swirl Type, (b) Venturi Type MBG.

Figure 7 illustrates that the bubbles produced predominantly measure around 100 µm in diameter across both types of Microbubble Generators (MBG). Notably, the venturi type MBG exhibits a higher frequency of microbubbles compared to its

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swirl type counterpart. This phenomenon can be attributed to the greater force generated by the venturi design, which effectively fractures larger bubbles into smaller ones. The force in the venturi type MBG arises from the turbulence induced by the venturi effect (Pambudiarto, 2020), whereas the swirl type MBG relies on tangential forces generated by rotational motion within the device.

CONCLUSION

Based on the research results, it can be concluded that (1) The swirl-type MBG outperforms other aerators in promoting fish growth. Key advantages include improved growth rates and better water quality maintenance, (2) Although the venturi-type MBG offers benefits in bubble size and oxygen transfer, its performance is hindered by air chamber blockages caused by environmental conditions. Design improvements are needed for the venturi-type MBG to address these blockage issues effectively, (3) The swirl-type MBG shows strong potential for high-density fish cultivation systems and future development.

RECOMMENDATION

To enhance the efficiency and usability of Microbubble Generators (MBG), it is essential to optimize their design and arrangement for improved ease of cleaning and installation. Streamlining these processes will facilitate better maintenance and operational effectiveness. Additionally, integrating Internet of Things (IoT) technology can provide real-time monitoring and data collection, enabling smarter management of aquaculture systems. Implementing solar panels will further promote sustainability by reducing energy consumption and reliance on non-renewable resources. The configuration of solar cell settings for the number of MBG aerators that can be used in high density tilapia cultivation needs to be studied to obtain optimal results. Together, these innovations will create a more resilient and environmentally friendly approach to fish farming, ultimately contributing to long-term sustainability in aquaculture practices.

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REFERENCES

Azhari, A., Abidin, Z., Muchlisin, and Dewiyanti, I., 2017, Pengaruh padat tebar terhadap kelangsungan hidup dan pertumbuhan benih ikan seurukan (*Osteochilus vittatus*), *Jurnal Ilmiah Mahasiswa Kelautan dan Perikanan Unsyiah*. 12 – 19.

Boyd, C.E., 1998, Water Quality for Pond Aquaculture, Department of Fisheries and Allied Aquacultures, Aubunr University, Alabama

Dampin, N., Tarnchalanukit, W., Chunkao, K., and Maleewong, M., 2012, Fish Growth Model for Nile Tilapia (Oreochromis niloticus) in Wastewater Oxidation Pond, Thailand. *Procedia Environmental Sciences*, 13, 513 – 524

Diansari, R. R. V. R., Arini, E., and Elfitasari, T., 2013, Pengaruh kepadatan yang berbeda terhadap kelulushidupan dan pertumbuhan ikan nila (*Oreochromis niloticus*) pada sistem resirkulasi dengan filter Zeolit. *Journal of Aquaculture Management and Technology*. 2(1), 37 – 45

Heriyati, E., Rustadi, R., Isnansetyo, A., Triyatmo, B., Istiqomah, I., Deendarlianto, D., and Budhijanto, W., 2022, Microbubble Aeration in A Recirculating Aquaculture System (RAS) Increased Dissolved Oxygen, Fish Culture Performance, and Stress Resistance of Red Tilapia (Oreochromis sp.). *Trends in Sciences*, 19

Hertanto, M., A., 2013, Produksi ikan nila (Oreochromis niloticus) jantan menggunakan madu lebah hutan. *Jurnal Bioteknologi Universitas Atmajaya Yogyakarta*, 1 – 13.

Juwana, W. E., Widyatama, A., Majid, A. I., Budhijanto, W., Indarto, and Deendarlianto, 2018, The application of digital image analysis to study the characteristic of bubble size distribution produced by orifice type microbubble generator, Proc. Of the 9th International Conference on Thermofluids 2017.

Juwana, W. E., Widyatama, A., Dinaryanto, O., Budhijanto, W., Indarto, and Deendarlianto, 2019, "Hydrodynamic characteristics of the microbubble dissolution in liquid using orifice type microbubble generator". *Chemical Engineering Research and Design*, 141(1)

Lakani, F. B., Sattari, M., and Falahatkar. B., 2013, Effect of Different Oxygen Levels on Growth Performance, Stress Response and Oxygen Consumption in 2 Weight Groups of Great Sturgeon Huso Huso. *Iranian Journal of Fisheries Sciences*, 12(1), 553-549.

Li, P., 2006, Dissertation: Development of Advanced Water Treatment Technology Using Microbubble, Kejo University.

Mallya, Y., J., 2007, The Effects of Dissolved Oxygen on Fish Growth in Aquaculture, Kingolwira National Fish Farming Centre, Fisheries Division Ministry of Naturan Resources and Tourism, Tanzania.

Mawarni, D. I., Juwana, W. E., Yuana, K. A., Budhijanto, W., Deendarlianto, and Indarto, 2022, "Hydrodynamic characteristics of the microbubble dissolution in liquid using the swirl flow type of microbubble generator". *Journal of Water Process Engineering*. 48(1).

Pambudiarto, B. A., Mindaryani, A., Budhijanto, W., and Deendarlianto, 2020, Evaluation of the Effect of Operating Parameters on the Performance of Orifice/Porous Pipe Type Micro-bubble Generator, *Journal of Engineering and Technological Sciences*, 52(2)

Parmar, R., and Majumder, S., K., 2013, Micro-bubble generation and microbubble-aided transport intersection – A state of the art report -, Chemical Engineering and Process: Process Intensification, 64(1), 79 - 97

Perikanan, K., K., 2022, "No title". https://www.kkp.go.id/ (accessed 28 Feb, 2024)

Ronald, N., Gladys, B., and Gasper, E., 2014, The Effects of Stocking Density on the Growth and Survival of Nile Tilapia (Oreochromis niloticus) Fry at Son Fish Farm. *Journal of Aquaculture Research & Development*.

Salsabila, M., and Suprapto, H., 2018, Enlargement Technique of Tilapia (Oreochromis niloticus) in Freshwater Aquaculture Installation Pandaan, East Java. *Journal of Aquaculture and Fish Health*, 7(3).

Susanto. H., 2000, Budi Daya Ikan di Pekarangan, Penebar Swadaya, Jakarta.

Wahyuningsih, S., and Gitarama, A. M., 2020, Amonia pada sistem budidaya ikan. *Jurnal Ilmiah Indonesia*. 5(1), 112 - 113

Wu, M., Song, H., Liang, X., Huang, N., and Li, X., 2022, Generation of micronano bubbles by self-developed swirl-type micro-nano bubble generator, *Chemical Engineering and Processing – Process Intensification*, Vol.181.