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Field-scale evaluation of a solar-powered double-nozzle venturi aeration system for water quality management in Tilapia Cage Culture

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Abstrak. Akuakultur memerlukan sistem aerasi yang efisien dan terjangkau untuk menjaga kualitas air, terutama pada perairan tenang atau dengan sirkulasi rendah, ketika penurunan oksigen terlarut (DO) dapat mengancam kelangsungan hidup dan produktivitas ikan. Penelitian ini mengevaluasi kinerja skala lapangan generator gelembung Venturi dua nosel bertenaga surya untuk aerasi malam hari pada keramba apung nila berukuran besar. Sistem dipasang pada keramba 11 m × 17 m berisi sekitar 6000 ekor nila, menggunakan delapan aerator Venturi dua nosel yang digerakkan pompa DC 12 V dan didukung sistem fotovoltaik-baterai off-grid. Aerator dioperasikan selang-seling pukul 00.30–08.30 dengan siklus 30 menit menyala dan 30 menit mati, setara 4 jam operasi efektif per hari. Setiap unit menghasilkan laju aliran air rata-rata 6,73 L/menit dan laju entrainment udara 1,12 L/menit, sedangkan pompa mengonsumsi daya 63,12 W. Kapasitas baterai minimum yang dibutuhkan sebesar 449,28 Ah dipenuhi oleh baterai 500 Ah, dan sistem fotovoltaik juga memadai sesuai kondisi radiasi surya setempat. Hasil lapangan menunjukkan pH stabil pada kisaran 6,7–7,3, sedangkan DO menjadi parameter pembatas utama. Air tanpa aerasi turun hingga 3,8 mg/L pada pagi hari, sementara air teraerasi mampu dipertahankan pada 4,5 mg/L. Temuan ini menunjukkan bahwa sistem tersebut layak secara teknis dan efektif untuk mengurangi penurunan oksigen malam hari pada budidaya nila off-grid.

Kata kunci: aerasi, venturi bubble generator, energi surya, dissolved oxygen, keasaman air

Abstract. *Freshwater aquaculture requires efficient and affordable aeration to maintain water quality, especially in stagnant or low-circulation waters where dissolved oxygen (DO) depletion can reduce fish survival and productivity. This study evaluated the field-scale performance of a solar-powered double-nozzle Venturi bubble generator for nighttime aeration in a large tilapia floating cage. The system was installed in an 11 m × 17 m cage containing about 6000 tilapia and used eight double-nozzle Venturi aerators driven by a 12 V DC pump with an off-grid photovoltaic-battery supply. It operated intermittently from 00:30 to 08:30 using a 30 min ON/30 min OFF cycle, equivalent to 4 h day^{-1} of effective operation. Each unit produced an average water flow of 6.73 L min^{-1} and air entrainment of 1.12 L min^{-1}, while the pump consumed 63.12 W. A minimum battery capacity of 449.28 Ah was required and met by a 500 Ah battery bank, while the photovoltaic system was adequately sized for local solar conditions. Field results showed stable pH (6.7–7.3), while DO became the main limiting factor. Aerated water maintained 4.5 mg L^{-1} DO compared with 3.8 mg L^{-1} in non-aerated water, confirming the system's feasibility and effectiveness for off-grid tilapia cage culture.*

Keywords: *aeration, venturi bubble generator, solar energy, dissolved oxygen, water acidity*

INTRODUCTION

Freshwater fish are a promising source of animal protein because they can be bred and grown more rapidly than conventional livestock such as cattle and poultry. For this reason, freshwater aquaculture has an important role in supporting food security and public health. Indonesia has favorable climatic conditions for freshwater fish farming, yet its production has not kept pace with the growing international demand. One of the major constraints is the limited application of appropriate technology in this sector. In many regions, production still relies on traditional shallow ponds that require large land areas, while rising land prices make further expansion increasingly difficult. In addition, farmers often depend on flowing streams to maintain water quality, a practice that can increase downstream organic loading and contribute to local clean water shortages [1].

These limitations highlight the importance of efficient aeration systems for improving productivity and environmental sustainability in freshwater aquaculture. Effective aeration can support deeper or more intensive culture systems, reduce land requirements, improve water quality, and create opportunities for water recirculation [1]. However, aeration is one of the largest operating costs in aquaculture after larvae and feed [2]. At present, most aerators used in freshwater aquaculture are surface aerators, particularly paddle-wheel systems [2], [3], which are often too costly for many small-scale Indonesian farmers.

Aeration refers to the process of bringing air and water into close contact to enhance oxygen transfer through mixing, circulation, or air dissolution. It is widely used in aquaculture and wastewater treatment, where higher dissolved oxygen accelerates aerobic processes [4]–[6]. In general, aerators can be divided into surface aerators and diffused aerators. The latter are commonly preferred in industrial applications because they provide higher Standard Aeration Efficiency (SAE) [6]. Among diffused systems, Venturi aerators are particularly attractive because they entrain air naturally through a pressure drop generated in a constricted throat, following Bernoulli's principle, without requiring an external compressor [7]. A

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typical Venturi bubble generator consists of a nozzle section, a suction chamber, and a divergent section [8]. Owing to their simple construction, low energy demand, robustness, and relatively low maintenance, Venturi systems have become increasingly attractive for aeration applications [9].

The main advantage of Venturi-based aeration lies in its ability to generate fine bubbles, which increase interfacial area and improve oxygen transfer [10]. Under appropriate conditions, Venturi aerators can produce bubbles with mean diameters below 100 µm, thereby enhancing mass transfer and mixing efficiency [11]. The Venturi microbubble generator (VMBG) operates by generating low-pressure zones that intensify fluid motion and cavitation, thus promoting microbubble formation [12]. Previous studies have shown that Venturi performance is strongly influenced by bubble breakup mechanisms, geometric design, operating pressure, and flow conditions. Huang et al. [13] reported that a micro-scale Venturi bubble generator produced bubbles with average diameters of about 0.2–0.4 mm, with bubble breakup mainly governed by shear stress, shear-off, and interfacial instability. They further showed that recirculation in the diverging section prolonged bubble residence time and intensified energy transfer between turbulence and bubbles. Goo et al. [14] found that bubbles generated by a Venturi-nozzle system ranged from 0.8 to 3.1 mm at the tube inlet and increased significantly in diameter toward the outlet, while the vertical rise height of bubbles increased from 41% to 89% along the tube. Yadav et al. [15] optimized SAE using an ANN-PSO approach and reported optimal operating parameters of L = 1.82 mm, d = 2.00 mm, and Q = 0.31 l/s, resulting in an SAE of 0.8333 kg O_2/kWh.

Further studies have examined the roles of pressure, discharge, and geometry in determining aeration performance. Panich et al. [16] showed that increasing pressure reduced bubble size and improved dissolved oxygen concentration, with the best performance achieved at 6 kg/cm^2, where bubbles of 46.13 µm produced dissolved oxygen levels of 7.40 mg/l and the highest oxygen transfer parameters. Catrawedarma et al. [17] found that increasing air discharge enlarged bubble size in all tested bubble generators, including Venturi systems, although the magnitude of this increase varied by design. Nadumaran and Elias [12] demonstrated that smaller throat diameters, longer throat lengths, and larger divergent angles significantly affected velocity, turbulence, vorticity, and bubble formation. Overall, these studies confirm that Venturi aeration performance depends strongly on structural and operational parameters.

Despite these advances, most previous studies have been limited to laboratory-scale experiments or controlled operating conditions and have mainly focused on bubble size, hydrodynamics, and aeration efficiency. Studies that assess Venturi aeration under real aquaculture conditions remain limited, particularly for large-scale tilapia cage systems. More importantly, there is still a lack of research evaluating the hourly variation of water quality during practical Venturi aeration operation, even though water quality parameters can fluctuate considerably throughout the day and directly influence fish health and culture performance. This unresolved issue represents an important research gap between engineering-based Venturi studies and their field-scale application in aquaculture.

Therefore, this study aims to evaluate the practical effectiveness of a double-nozzle Venturi bubble generator, previously developed in our earlier study [18], in a large-scale tilapia cage system. The system was applied in a fish cage measuring 11 m × 17 m with a population of approximately 6000 tilapia. To support sustainable operation, the pump was powered by a solar energy system integrated with battery storage. By monitoring water quality under actual field conditions, this study seeks to determine the feasibility of the proposed aeration system as an energy-efficient and practical solution for large-scale tilapia farming. The novelty of this study lies in its field-scale evaluation of a double-nozzle Venturi bubble generator under practical aquaculture conditions, with particular emphasis on hourly water quality dynamics in a large tilapia cage system powered by renewable energy. This approach helps bridge the gap between laboratory-based Venturi aeration studies and the operational needs of real aquaculture production systems.

METHODS

Aeration system

The aeration system was deployed in a tilapia floating cage installed in a lake with very low water circulation, where dissolved oxygen availability was considered insufficient for intensive fish culture. The cage measured 11 m × 17 m with a water depth ranging from approximately 1.5 to 3.0 m, and it contained approximately 6000 tilapia. Since dissolved oxygen depletion typically occurs at night due to the absence of photosynthesis by aquatic plants and phytoplankton, the aeration system was operated only during nighttime.

The aeration unit consisted of eight double-nozzle venturi bubble generators driven by a 12 V, 5.4 A DC water pump. Electrical power was supplied by a battery system charged by a solar photovoltaic (PV) module through a PWM solar charge controller, enabling off-grid operation under field conditions.

The aerator was operated intermittently from 00:30 to 08:30, with a cycle of 30 min ON and 30 min OFF. Accordingly, the effective daily operating time of the pump was 4 h day^{-1}. This intermittent strategy was selected to reduce energy consumption while maintaining oxygen supply during the critical nighttime period.

The geometry of the double-nozzle venturi bubble generator is illustrated in Figure 1. The water inlet diameter (D_1), air inlet diameter (D_2), and outlet diameter (D_3) were ½ inch, ½ inch, and 10 mm, respectively, with a total length of 120 mm. Air inlet holes with a diameter of 1 mm were introduced in the throat section to facilitate air entrainment induced by the pressure drop within the venturi.

To simplify fabrication and enable rapid production, the venturi bubble generator was manufactured using 3D printing. This approach allowed the production of a simple, low-cost, and reproducible aeration component suitable for field application.

Prior to field installation, an initial performance test of the venturi bubble generator was conducted. During the test, the unit was submerged to a depth of 20 cm below the water surface. The purpose of this test was to determine the hydraulic discharge, air entrainment rate, and pump power consumption under the selected operating condition.

The results showed that the average water flow rate was 6.73 L min^{-1}, while the average air flow rate was 1.12 L min^{-1}. The electrical power consumed by the pump during operation was 63.12 W. These parameters were subsequently used as the basis for designing the battery and solar PV configuration.

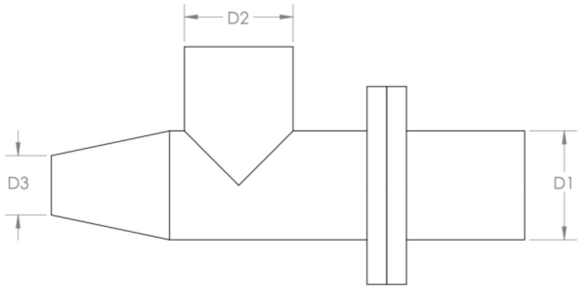

Figure 1. Double-nozzle venturi bubble generator

Power Supply

The battery capacity was determined from the daily electrical load of the pump. The daily pump load was calculated from the pump current, number of pumps, and effective daily operating duration, as given in Eq. (1).

$$\mathbf{L_p = I_p \times N_p \times t} \quad (1)$$

where L_p is the daily pump load (Ah day^{-1}), Ip is the pump current (A), N_p is the number of pumps, and t is the effective operating time (h day^{-1}). To account for system losses and charging requirements, a charge-to-load ratio (C:L ratio) of 1.3, as suggested by Chow (2010) [19], was applied. Thus, the required daily battery load was determined in Eq. (2).

$$\mathbf{L_b = L_p \times C_L} \quad (2)$$

where L_b is the daily battery load (Ah day^{-1}), and C_L is the charge-to-load ratio. The battery was designed using a depth of discharge (DOD) of 50%, following the literature [20]. The minimum battery capacity was therefore calculated using Eq. (3).

$$\mathbf{C_b = \frac{L_b}{DOD}} \quad (3)$$

where C_b is the required battery capacity (Ah), and *DOD* is expressed in decimal form. The capacity of the solar PV system was determined based on the daily battery load and the local peak sun hours (PSH). The PSH value was obtained by entering the installation location into the Footprint Hero peak sun hours calculator [21]. After obtaining the PSH value, the total current requirement of the solar PV system was calculated using Eq. (4).

$$\mathbf{I_{PV,total} = \frac{I_b}{PSH}} \quad (4)$$

where $I_{PV,total}$ is the total PV current requirement (A), L_b is the daily battery load (Ah day^{-1}), and *PSH* is the peak sun hours (h day^{-1}). If multiple PV modules were used, the minimum current requirement for each module was determined using Eq. (5).

$$\mathbf{I_{PV,module} = \frac{I_{PV,total}}{N_{PV}}} \quad (5)$$

where $I_{PV,module}$ is the minimum current of each PV module (A), and N_{PV} is the number of solar PV modules. The complete aeration system, consisting of the venturi bubble generators, DC pump, battery, solar PV modules, and PWM controller, was installed and operated in the tilapia cage during nighttime. The system was intended to enhance oxygen transfer under stagnant water conditions, especially during periods when natural oxygen replenishment was limited.

In summary, the system design, laboratory testing, and field installation leading to the conclusion are illustrated in Figure 2.

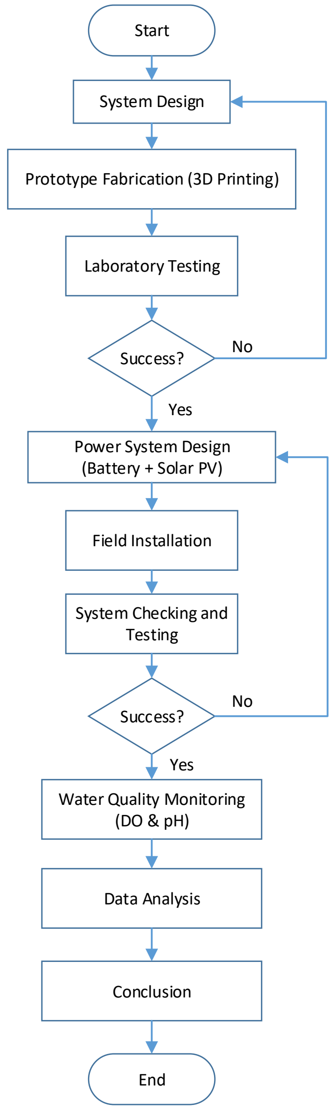

Figure 2. Workflow of the solar-powered Venturi aeration system

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RESULTS AND DISCUSSION

Aeration and Power Supply Design

The preliminary test demonstrated that the double-nozzle venturi aerator operated effectively under the selected condition. At a submergence depth of 20 cm, the unit produced an average water discharge of 6.73 L min^{-1} and an average air entrainment rate of 1.12 L min^{-1}. The measured pump power consumption was 63.12 W, which was close to the rated value of 64.8 W calculated from the pump specification (12 V, 5.4 A). This small difference indicates that the nominal electrical rating was appropriate for subsequent power system design.

With eight aeration units installed, the system provided a combined water flow rate of 53.84 L min^{-1} and an air flow rate of 8.96 L min^{-1} during operation. These results confirm that the venturi system was capable of entraining atmospheric air and supplying additional aeration to the cage water under stagnant conditions. The intermittent operating mode, consisting of 30 min ON and 30 min OFF from 00:30 to 08:30, reduced energy consumption while maintaining aeration during the critical nighttime period when dissolved oxygen depletion is most likely to occur.

Based on the pump current, number of pumps, and effective operating duration, the daily pump load was calculated as 172.8 Ah day^{-1}. After applying a charge-to-load ratio of 1.3, the daily battery load increased to 224.64 Ah. Using a battery depth of discharge of 50%, the minimum required battery capacity was 449.28 Ah.

Accordingly, the system was equipped with five 100 Ah batteries, providing a total nominal capacity of 500 Ah. This configuration exceeded the minimum requirement and provided a practical safety margin for field operation. The selected battery bank was therefore sufficient to support nighttime aeration while avoiding excessive discharge that could shorten battery life.

The solar PV system was designed using a local peak sun hours (PSH) value of 5.49 h day^{-1}. Based on the daily battery load, the required total PV current was 40.92 A. For a five-module configuration, the minimum current requirement per module was approximately 8.12 A.

A 200 Wp monocrystalline PV module with a maximum power current (Imp) of 10.96 A was therefore selected. This value exceeded the calculated minimum requirement, indicating that the PV array was adequately sized to recharge the battery bank under local solar conditions. The use of monocrystalline panels was also appropriate due to their relatively high efficiency, compact area requirement, and good thermal stability, which are advantageous for off-grid aquaculture applications [22]. The aeration powered by solar PV system is illustrated in Figure 3, and the on site installation is depicted in Figure 4.

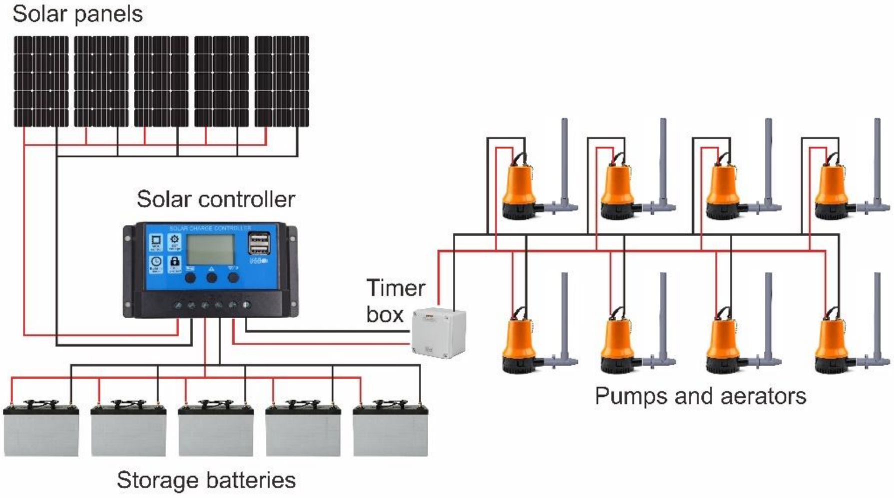

Figure 3. Aeration powered by solar PV system

Figure 4. On site Aeration powered by solar PV system installation; a. top view, b. aeration configuration

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The results indicate that the aeration and power supply systems were appropriately matched for nighttime operation in a floating tilapia cage under low-circulation conditions. The venturi aerators generated measurable air entrainment, while the intermittent operating strategy reduced the overall energy demand to a level compatible with standalone solar-battery operation. The battery bank provided sufficient storage capacity, and the selected PV modules offered adequate charging capability with an additional design margin.

Overall, the proposed system demonstrates the technical feasibility of using a solar-powered venturi aeration system to support intensive tilapia culture in off-grid stagnant waters. The design is also practical for field implementation due to its moderate energy demand, simple component configuration, and suitability for autonomous operation.

Water Quality Observation

The dissolved oxygen (DO) profile in the non-aerated tilapia cage showed a clear diurnal pattern during both 24-hour observation periods tested using a digital dissolved oxygen analyzer (Figure 5). In general, DO was relatively high in the late afternoon, gradually declined during the night, reached its lowest level in the early morning, and then increased again after sunrise toward midday and afternoon. This pattern is commonly observed in aquaculture waters because oxygen production by photosynthesis occurs during the day, whereas respiration by fish, aquatic plants, phytoplankton, and other organisms continues throughout the night. In a lake area with limited water circulation, such fluctuations may become more pronounced because the natural replenishment of oxygen from surrounding waters is restricted.

Although the general pattern was similar on both days, the magnitude of DO fluctuation differed. On the first day, DO decreased from 9.2 mg/L at 16:25 to 5.2 mg/L at 06:25, then increased again and reached 10.7 mg/L at 11:25. All DO values on the first day remained above the corrected minimum standard of 4 mg/L (PP No. 82 Tahun 2001 (kelas II)), indicating that the water quality was still acceptable throughout the observation period. On the second day, DO started at 10.3 mg/L at 16:25 but declined more sharply during the night, reaching 3.8 mg/L at 07:25 before recovering to 9.0–9.4 mg/L in the afternoon. This indicates that the cage water temporarily failed to meet the DO standard on the second day during the early morning.

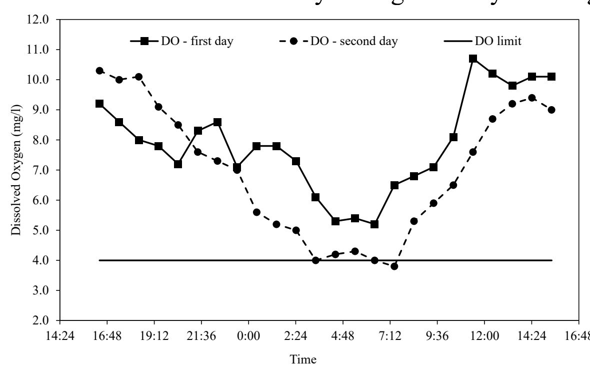

Figure 5. Dissolved oxygen (mg/l)

The difference between the two days can be explained by the contrasting weather conditions. On the first day, the sky was clear and cloudless, which likely allowed stronger wind movement over the lake surface. Under such conditions, air more frequently contacts the water surface, enhancing oxygen diffusion and transfer from the atmosphere into the water. This process may have helped maintain higher DO concentrations and prevented oxygen levels from falling below the minimum standard. This condition is related to the literature that the wind-induced reaeration plays a critical role in oxygen transfer at the air–water interface [23].

In contrast, the second day was cloudy, and such weather conditions likely reduced effective wind movement over the water surface. As a result, air–water contact was less intense, and oxygen transfer from the atmosphere to the water body was reduced. This lower reaeration capacity likely contributed to the sharper nocturnal DO decline observed on the second day. Thus, even within the same cage location, short-term meteorological variation appears to have had an important influence on oxygen availability. The recorded weather situation around the location is depicted in Figure 6, where the first and second days' data were recorded at 22 and 23 July 2024, respectively, starting from 4.25 pm. During the first observation day, average wind speed was estimated at 4 to 9 m/s from evening to morning, whereas the second day experienced overcast conditions with reduced wind intensity (0-7 m/s).

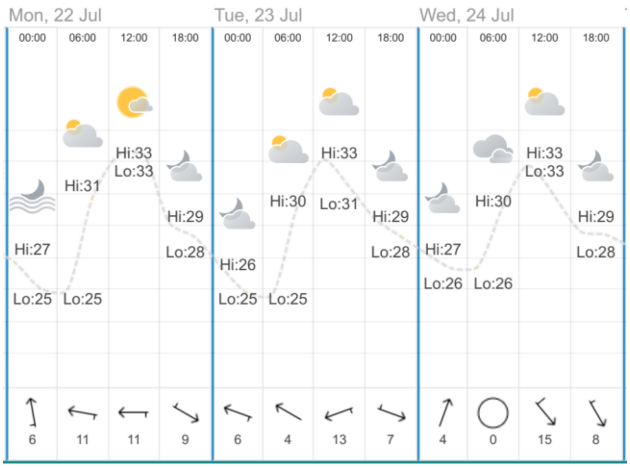

Figure 6. Weather situation recorded at the time of data taken

The pH data recorded using a digital pH meter showed a narrower range of fluctuation than DO. On the first day, pH ranged from 6.9 to 7.3, while on the second day it ranged from 6.7 to 7.3 (Figure 7). All recorded values remained within the acceptable range of 6.5 to 8.5 (PP No. 82 Tahun 2001 (kelas II)), indicating that the acidity condition of the cage water was suitable for tilapia culture during the entire monitoring period. Overall, the pH values were close to neutral, showing that the water did not experience either acidic or alkaline stress.

A daily trend was also observed in the pH profile. At night and in the early morning, pH tended to be lower than during the daytime. This condition is closely related to biological activity in the water. During daylight hours,

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aquatic plants and phytoplankton produce oxygen through photosynthesis and simultaneously consume carbon dioxide. The reduction in dissolved carbon dioxide decreases carbonic acid formation and tends to increase pH. At night, however, photosynthesis ceases because of the absence of sunlight, while respiration continues. Under this condition, oxygen is consumed and carbon dioxide accumulates in the water, leading to slightly lower pH values. This explains why both DO and pH were generally lower at night than during the day.

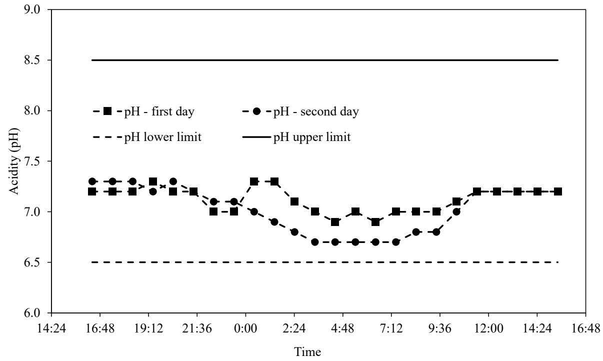

Figure 7. Water acidity (pH)

The DO and pH data show a consistent temporal relationship. In both observation days, lower DO values at night and in the early morning were accompanied by slightly lower pH values, while increasing DO during the daytime coincided with a rise in pH. This indicates that both parameters were controlled by the same fundamental biological processes, namely the balance between photosynthesis and respiration. During the day, photosynthesis by aquatic plants and phytoplankton increases oxygen concentration and reduces carbon dioxide, resulting in higher DO and slightly higher pH. At night, in the absence of photosynthesis, respiration dominates, causing oxygen depletion and carbon dioxide accumulation, which in turn lowers both DO and pH.

However, the extent of fluctuation was much greater for DO than for pH. DO varied widely, from a maximum of 10.7 mg/L on the first day and 10.3 mg/L on the second day to a minimum of 5.2 mg/L and 3.8 mg/L, respectively. In contrast, pH remained within a narrow interval of 6.7–7.3. This shows that DO was the more sensitive indicator of short-term water quality change in the cage system. While pH consistently remained within the suitable range, DO on the second day dropped below the standard, indicating that oxygen availability rather than acidity was the primary water quality constraint under limited-circulation conditions.

The comparison between aerated and non-aerated water further highlights the importance of oxygen replenishment in the cage environment (Figure 8). The comparison between aerated and non-aerated water indicates that the influence of the Venturi aeration system was most pronounced during the critical nighttime to early morning period, when dissolved oxygen declined naturally due to the absence of photosynthesis and continuous respiration in the cage system. At 00:25, the non-aerated water recorded a DO concentration of 5.6 mg/L, while the aerated water showed a higher value of 6.1 mg/L. A similar trend was observed at 03:25, where DO increased from 4.0 mg/L under non-aerated conditions to 4.7 mg/L under aerated conditions. The most important difference occurred at 07:25, when the DO concentration in non-aerated water dropped to 3.8 mg/L, below the minimum standard of 4.0 mg/L, whereas the aerated water maintained DO at 4.5 mg/L. This indicates that the aeration system helped prevent oxygen depletion during the most critical period before sunrise.

Outside the nighttime aeration period, particularly during daytime and late afternoon, the DO values between the two conditions were relatively close. This suggests that natural oxygen production through photosynthesis and atmospheric reaeration became the dominant factors controlling DO concentration during the day. Therefore, the role of the Venturi aeration system should be interpreted primarily as a protective measure during nocturnal oxygen depletion rather than as a continuous DO enhancement mechanism throughout the entire observation period.

These results indicate that aeration played an important protective role during the night and early morning by maintaining oxygen above the critical threshold. This finding is especially relevant for cage aquaculture in lake areas with limited water circulation, where natural oxygen replenishment may be insufficient under cloudy conditions or during periods of weak wind.

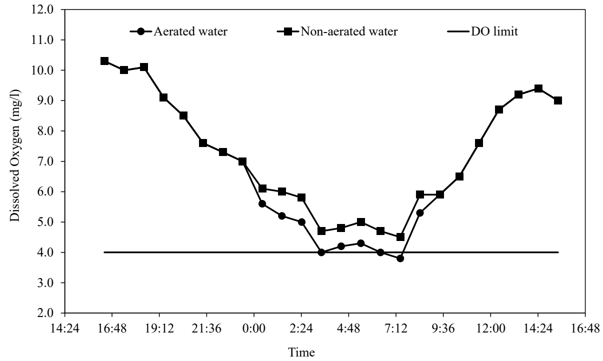

Figure 7. Aerated and non-aerated dissolved oxygen in water.

Overall, the water quality in the tilapia cage was mainly influenced by diel changes in oxygen rather than by harmful changes in acidity. The pH remained within the acceptable range of 6.5–8.5 throughout the study, showing that acidity was not a limiting factor. In contrast, DO showed marked fluctuations, and the non-aerated water on the second day fell below the minimum acceptable level of 4 mg/L in the early morning. The difference between the two days suggests that weather conditions, particularly cloud cover and the resulting effect on wind-driven air–water contact, may strongly influence oxygen transfer and thus DO availability in low-circulation cage systems.

The findings also confirm that nighttime and early morning represent the most critical period for water quality assessment in tilapia culture. During this period, photosynthesis is absent, respiration continues, and atmospheric oxygen transfer may be limited, especially under cloudy conditions. As shown by the aeration comparison, supplemental aeration can reduce the risk of oxygen depletion and help maintain DO above the required standard. Therefore, in lake-based tilapia cages with limited circulation, water quality management should prioritize continuous DO monitoring, especially at night and before sunrise, while aeration should be considered an effective strategy to stabilize culture conditions.

CONCLUSSION

This study demonstrated the practical feasibility of applying a solar-powered double-nozzle Venturi aeration system in a large tilapia floating cage under low-circulation field conditions. The system delivered a total air entrainment rate of 8.96 L min^{-1} and maintained dissolved oxygen (DO) at 4.5 mg L^{-1} during critical early morning periods, compared to 3.8 mg L^{-1} in non-aerated conditions, representing an improvement of approximately 18.4%. The daily energy demand of 172.8 Ah was successfully supported by a 500 Ah battery system and a photovoltaic array sized based on 5.49 peak sun hours. While pH remained stable within 6.7–7.3, DO was identified as the primary limiting parameter. These results confirm that the proposed system is technically viable, energy-efficient, and capable of mitigating nocturnal oxygen depletion in low-circulation aquaculture systems. Future work should investigate long-term seasonal performance and optimize aerator placement for improved oxygen distribution.

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AUTHORS CONTRIBUTION

Thoharudin: Writing – original draft, Conceptualization, Methodology, Investigation. Sunardi: Investigation, Methodology. Fitroh Anugrah Kusuma Yudha: Conceptualization, review & editing. Muhammad Nadjib: Conceptualization, Methodology. Aqiel Zahrivan Asyara Pudjianto: Investigation.

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