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RESEARCH PAPER

Evaluating Water Quality in White Shrimp Aquaculture: A Case Study in Round Ponds with Venturi Pump Systems During the Blind Feeding Phase

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Abstract

White shrimp (*Litopenaeus vannamei*) production has been steadily expanding. To enhance white shrimp aquaculture, innovative techniques like circular ponds and venturi pumps have gained attention due to their potential to increase productivity. A crucial stage in white shrimp cultivation is the blind feeding period. Water quality plays a pivotal role in the success of aquaculture systems, especially during this phase, yet there is a notable lack of comprehensive data on water quality dynamics in circular ponds employing venturi pump systems. This study delves into the intricate water quality dynamics during white shrimp cultivation in round pond systems with venturi pumps, with a specific focus on the blind feeding period. Our findings indicate that various parameters meet the required quality standards for successful shrimp cultivation, including water temperature, salinity, brightness, conductivity, nitrite, nitrate, orthophosphate, total ammonia nitrogen (TAN), sulfur hydrogen (sulfide), and total organic matter (TOM). Even when orthophosphate and nitrate levels exceed ideal thresholds, the shrimp exhibit robust growth, showcasing their adaptability to changing conditions. This research emphasizes the significant potential of circular pond systems with venturi pumps for white shrimp cultivation, contributing to the development of efficient and sustainable aquaculture practices and ultimately boosting productivity in the sector.

Introduction

White shrimp (*Litopenaeus vannamei*) remains a key commodity in the global aquaculture industry due to its rapid growth, high market demand, and adaptability to diverse environmental conditions (Hidayani et al., 2015; Ariadi et al., 2019). However, traditional shrimp farming systems often require extensive land areas and significant financial investment, creating barriers for small-scale farmers and young entrepreneurs (Boyd et al., 2020; Castro et al., 2021). To address these challenges, innovative aquaculture approaches, such as coastal urban farming, have been introduced as sustainable solutions to optimize land use and reduce operational costs (Diehl et al., 2020).

One emerging method in shrimp aquaculture is the use of circular tank systems equipped with venturi pumps. These systems offer several advantages, including improved water circulation, enhanced oxygen distribution, and efficient waste removal (Kumaran et al., 2017; Boyd & McNevin, 2021). A venturi pump is a water circulation device designed to increase water flow velocity and oxygenation through a pressure differential created by narrowing the flow path. This mechanism not only enhances dissolved oxygen levels but also prevents stagnation, reduces the accumulation of harmful substances, and maintains a consistent water quality environment. The venturi pump used in this study is custom-designed for circular ponds with specifications detailed in the Materials and Methods section.

Another critical aspect of shrimp farming is the blind feeding phase, a 35-day period at the beginning of the cultivation cycle during which shrimp are fed based on estimated consumption rather than direct observation. This phase is crucial as shrimp undergo rapid growth, and optimal water quality conditions are essential to support their metabolic and physiological needs (Pramudia et al., 2022; Suantika et al., 2018). While the blind feeding phase offers practical benefits, such as labor efficiency and reduced stress on shrimp from frequent human interaction, it also presents challenges, including the potential for overfeeding, nutrient imbalances, and water quality degradation.

Despite the growing adoption of circular tanks with venturi pumps, limited research exists on their performance during the blind feeding phase, particularly in understanding water quality dynamics and their impact on shrimp growth. This study aims to address these knowledge gaps by evaluating key water quality parameters in circular tanks equipped with venturi pumps throughout the blind feeding phase. The findings are expected to provide valuable insights into optimizing water quality management and enhancing productivity in shrimp aquaculture systems.

Materials and Method

Round Pond and Venturi Pump Description

The vaname round pool has a diameter of 10 meters and a pool wall height of 1.2 meters (Figure 1.a). The pool's frame is constructed using wire mesh and covered with a High-Density Polyethylene (HDPE) membrane. It is equipped with a central drain and a drainage system situated in the middle of the pool, featuring a pool bottom slope of 2–3% toward the center. The venturi pump is positioned at the pool's edge, and its rotation direction is clockwise on both sides. This arrangement ensures that debris on the pool's bottom accumulates in the center and can be periodically removed through the central drain. The venturi pump was custom-designed to accommodate a circular pool with a 10-meter diameter. The pump's specifications can be found in Table 1, and a detailed description of its shape and installation is provided in (Figure 1.b) This study used 3 different ponds to replicate the experiments. All the measurements were repeated three times independently.

Daily Water Quality Parameters

Total Dissolved Solids

Total dissolved solids (TDS) and temperature were measured using a Multi-parameter (Lutron-YK-22CTA, USA). The probe is inserted into the pool water once the tool is turned on and ready. The measurement results are recorded after the number shows that the value of TDS or temperature is stable. Measurements were taken every morning and evening at 6 a.m. and 4 p.m.

Water Flow Velocity

Water flow velocity measurements were carried out using a current meter (Flowatch FL-03, JDC

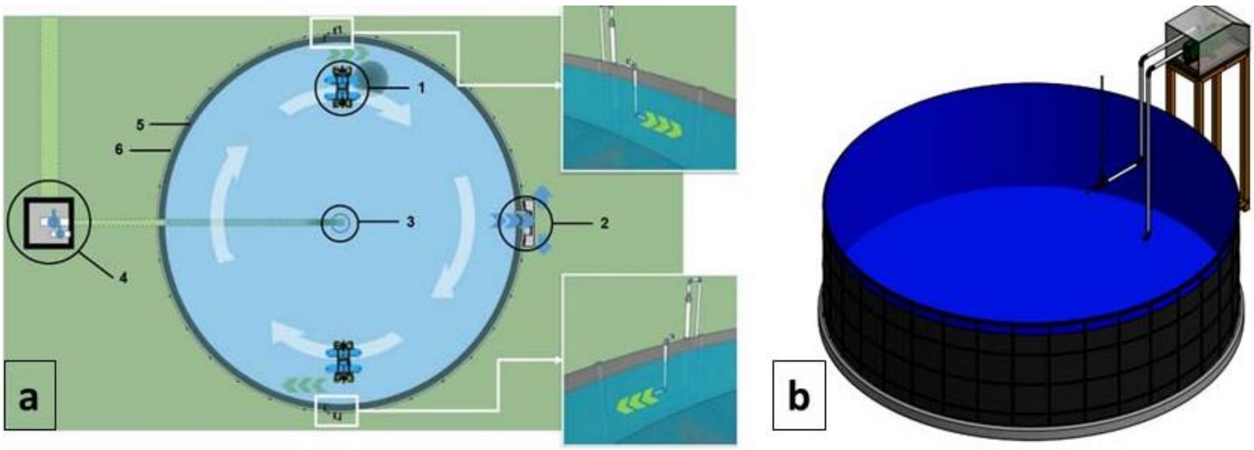

Figure 1. (a) An overview of the circular pond design used for cultivating white shrimp in this study; (1) Venturi pump; (2) top outlet; (3) central drain; (4) bottom outlet channel; (5) HDPE membrane; (6) Wiremesh frame. **(b)** Overview of the design and installation of a venturi pump in a round pond for cultivating white shrimp.

Table 1. Specification of venturi pump designed for round ponds for white shrimp aquaculture

Criteria	Specification
Electrical input	0.35 kW
Electrical output	150 W
Maximum suction power	11 meter
Maximum capacity	55 L/minute
Suction pipe diameter	1 inch
Outlet pipe diameter	1 inch

Instrument, Switzerland). The tool is turned on, and the rotor is inserted into the pool water. The rotor must be completely submerged and free from obstructions or obstacles affecting rotor movement. The measurement results will be displayed on the screen based on rotor rotation. Measurements were taken in the morning (6 a.m.) and afternoon (4 p.m.) daily.

Dissolved Oxygen

Dissolved oxygen was measured using a DO and BOD Meter (HI98193, Hanna Instruments, Italy). Once the tool is ready, the probe is inserted into the pool water. Measurements are carried out in "range" mode, with the results obtained using "Auto End" mode. Measurements were taken at 6 a.m. and 4 p.m.

pH

pH measurements in pond water were carried out directly using a Multi Water Quality Checker (WQC-22A, DKK TOA Corporation, Japan). The measurement process begins with calibrating the pH meter. Once ready to use, the probe from the pH meter is dipped into pond water and left until the pH value is stable. Measurements were taken at 6 a.m. and 4 p.m. and were carried out three times independently.

Temperature

Temperature was measured using a Multi-parameter (Lutron-YK-22CTA, USA). After the tool is turned on and calibrated, the probe is inserted into the pool water. In temperature measurements, the value is recorded after the read value is stable. Temperature measurements are taken twice a day, at 6 a.m. and 4 p.m.

Weekly Water Quality Parameters

Total Organic Matters

Total Organic Matter (TOM) levels were measured using the permanganometry titration method (Indonesian National Standard [SNI]: 06-6989.22-2004). TOM measurements are carried out every week for 35 days. The measurement procedure begins by inserting 50 mL of sterile distilled water into an Erlenmeyer flask as a control solution (x value). For sample measurements (y value), 10 mL of 0.01 N $KMnO_4$ and 5 mL of 6 N H_2SO_4 were added to 25 mL of sample, then homogenized and heated until boiling (ca. 70°C). Then, 10 mL of 0.01 N oxalic acid was added and homogenized until the color became clear. Next, titration was carried out using 0.01 N $KMnO_4$ until the color changed to purple. The titration results are used to analyze the TOM value based on the following formula:

$$\text{TOM (mg/L)} = \frac{(X-Y) \times 31{,}6 \times 0{,}01 \times 1000}{\text{Volume of sample (mL)}}$$

Where X is the volume of titrant for sample water (mL), Y is the volume of titrant for distilled water (mL), 31.6 is the relative molecular mass of $KMnO_4$, 0.01 is the molarity of $KMnO_4$, and 1000 is the conversion from mL to L.

Orthophosphate

Orthophosphate was measured using the spectrophotometric method (Indonesian National Standard [SNI]:06-6989.31-2005). 50 mL of water sample was put into an Erlenmeyer. Then, one drop of phenolphthalein indicator was added. If a pink color forms, add 5N H_2SO_4 until the color disappears. 8 mL of mixed solution (Sulfuric acid, Potassium antimonyl tartate, Ammonium molybdate, Ascorbic acid) was added and homogenized to the sample solution. The sample was put into a cuvette, and the absorbance was measured using a spectrophotometer (U-1900, Hitachi High- Technologies Corporation, Japan) at a wavelength of 880 nm. Orthophosphate concentration was calculated from the conversion of absorbance values. Orthophosphate measurements are carried out every week for 35 days.

Nitrite

Nitrite concentration measurements were carried out using the spectrophotometric method (Indonesian National Standard: 06-6989.9-2004). 50 mL of sample was put into a 200 mL beaker. Then, 1 mL of sulfanilamide solution was added, shaken, and left for 2 minutes to 8 minutes. Then, 1 mL of NED dihydrochloride solution was added, shaken, and left for 10 minutes. Samples are measured using a spectrophotometer (U-1900, Hitachi High- Technologies Corporation, Japan) at a wavelength of 543 nm (measurements should not be carried out for more than 2 hours). Calculation of nitrite levels is done by converting absorbance numbers into concentrations. Nitrite measurements were carried out every week for 35 days.

Total Ammonia Nitrogen

Testing for total ammonia nitrogen levels uses the spectrophotometric method (Indonesian National Standard [SNI]: 06-6989.30-2005). 25 mL of sample was put into an Erlenmeyer. Next, 1 mL of phenol was added and homogenized. To the solution obtained, 1 mL of sodium nitroprusside was added and homogenized. 2.5 mL of oxidizing solution was then added and homogenized. The Erlenmeyer was closed for 1 hour until color formation occurred. The sample was put into a cuvette, and the wavelength absorbance of 640 nm was measured using a spectrophotometer (U-1900, Hitachi High- Technologies Corporation, Japan). The TAN value is obtained by converting the absorbance value obtained. Total ammonia nitrogen measurements were carried out every week for 35 days.

Nitrate

Nitrate testing uses the spectrophotometric method (Indonesian National Standard [SNI]:06-6989.11-1990). 12.5 mL of sample was filtered and poured into a porcelain cup. The sample is evaporated on a hot plate until a crust forms and cools. 0.5 mL of phenol disulfonic acid was added to the sample and homogenized. The solution obtained was then diluted by adding 2.5 mL of distilled water. NH_4OH (1:1) was added until a yellow color was formed (maximum 7 mL) and diluted with distilled water to 12.5 mL. Next, the solution obtained was put into a cuvette to measure its absorbance with a spectrophotometer (U-1900, Hitachi High- Technologies Corporation, Japan) at a wavelength of 410 nm. The nitrate concentration value was converted from the absorbance value obtained. Nitrate measurements were carried out every week for 35 days.

Sulphide

Sulphide levels were measured using the spectrophotometric method (Indonesian National Standard [SNI]: 6989.70-2009), carried out every week for 35 days. The water sample is put into a 50 mL measuring flask. Dilution was done by adding sulfide-free water to the tera mark, 0.5 mL of sulfuric acid amine reagent, and 0.15 mL of $FeCl_3$. The resulting mixture was immediately inverted slowly and allowed to stand for ca. 5 minutes. Then 1.6 mL $(NH_4)2HPO_4$ was added and left for ca. 15 minutes. Absorbance with a wavelength of 664 nm was analyzed using a spectrophotometer (U-1900, Hitachi High- Technologies Corporation, Japan). The H_2S concentration is analyzed using the following formula:

$$H_2S\ (mg/L) = \frac{A}{(slope \times V)} + \frac{V_2}{V_1} \times f$$

Where A is the absorbance of the measured sample, V is the sample volume (mL), V1 is the final sample volume (mL), V2 is the initial sample volume (mL), and f is the dilution factor.

Shrimp Growth

Average Body Weight

Average Body Weight (ABW) measurements were conducted on the 1st, 30th, and 37th days after hatching (DOC). The 1st day was selected to establish a baseline measurement, providing an initial reference for shrimp size at the start of the cultivation period. Subsequent measurements on the 30th and 37th days were chosen to monitor growth trends during and after the critical blind feeding phase. After the 30th day, measurements were conducted weekly to ensure a more detailed assessment of growth dynamics during the later stages of the cultivation cycle. Sampling involved randomly selecting shrimp specimens from different areas of the pond, followed by individual weighing. ABW was calculated using the following formula:

$$ABW\ (gr/ind) = \frac{\text{Total weight (gr)}}{\text{Number of shrimp (ind)}}$$

The selected time points were chosen strategically to balance the need for growth monitoring with practical feasibility while minimizing stress on the shrimp.

Average Daily Growth

The calculation of Average Daily Growth (ADG) was carried out on the 1st, 30th, and 37th days after hatching (DOC). These intervals align with critical growth milestones, allowing for the assessment of both initial growth trends and later-phase development under the blind feeding method. After the 30th day, weekly measurements were introduced to capture growth patterns more comprehensively. ADG was determined using the following formula:

$$ADG\ (gr/day) = \frac{ABWn\ (gr/ind) - ABWt(gr/ind)}{T\ (day)}$$

This approach provides sufficient resolution to observe significant growth trends while minimizing disruptions to shrimp behavior and the pond ecosystem.

Results and Discussion

Monitoring water quality parameters is vital when assessing innovative aquaculture technologies due to their impact on organism well-being, production efficiency, ecosystem balance, and regulatory compliance (Tanjung et al., 2022). Compliance with legal regulations and industry standards is essential for sustainability and reputation in aquaculture practices (Amundsen et al., 2019). In evaluating the application of round pond with venturi pumps in white shrimp cultivation, daily and weekly water quality parameters were analyzed in this study.

Daily Water Quality Parameters

Total Dissolved Solids

Total Dissolved Solids (TDS), which describes the quantity of all dissolved solids in water, is analyzed in this study (Figure 2a). Measuring TDS is important because these dissolved solids can significantly impact the water quality and shrimp growth. This study measured TDS values in the morning (6 a.m.) and afternoon (4 p.m.). The results showed that the TDS level showed relatively minor variations.

The average TDS value on day 0 was around 3,503 mg/L, increased slightly to 3,737 mg/L on day 11, and reached 3,767 mg/L on day 35. This change is still within the ideal standard standards recommended for white shrimp cultivation, namely between 3,000 and 5,000 mg/L 2023) (McGraw & Scarpa, 2003). This relatively stable TDS value can indicate that water management during the blind feeding phase in the white shrimp aquaculture using a round pond and venturi pump system can occur well. Factors such as controlled feeding, good water circulation, and careful water quality management can contribute to the stability of TDS values. In this context, well-maintained water quality can be a factor that supports the health and productivity of white shrimp (Widiasa et al., 2023).

Water Flow Velocity

The condition of the pond ecosystem is also greatly influenced by the velocity of the water flow. The results of this study reveal that the velocity of water flow in the morning and evening is relatively constant (Figure 2b). The initial velocity set for the initial stage of cultivation is around 0.1 m/s. Furthermore, fluctuations in flow velocity occurred, where the value increased to 0.3 m/s on the third day and reached a peak of 0.4 m/s on the sixth day. However, after reaching the highest point, the water velocity decreased again, reaching around 0.25 m/s on the 7th day and gradually decreasing until it reached 0.1 m/s on the 11th to 15th day. Next, there was a gradual increase in the water flow velocity, reaching 0.3 m/s on the 18th day before decreasing again to 0.1 m/s on the 19th day. After this decrease, the water velocity tended to stabilize at that level until the end of the observation.

Although the water flow velocity experiences slight fluctuations when cultivating white shrimp in round ponds, generally, the flow velocity is still within the optimum limit for cultivating white shrimp (0.1 – 0.3 m/s). This flow velocity fluctuation is mainly caused by differences in water flow velocity produced by the venturi pump used in this study. These fluctuations can then be overcome by adjusting the outlet position of the venturi pump to remain stable during the cultivation process. These fluctuations reflect complex dynamics in aquaculture pond management and their impact on environmental parameters, including water flow velocity.

Dissolved Oxygen

Dissolved Oxygen (DO) is a critical parameter in white shrimp (*Litopenaeus vannamei*) aquaculture, influencing metabolic processes, feed utilization efficiency, and overall shrimp health (Boyd & Tucker, 1998; Emerenciano et al., 2022). Monitoring DO is essential to ensure optimal water quality, as oxygen levels directly affect shrimp growth rates, survival, and resistance to disease (Kumar et al., 2018).

In this study, DO measurements were conducted twice daily, in the morning (6 a.m.) and afternoon (4 p.m.) (Figure 2c). The results revealed that DO levels ranged between 6.5 and 10 mg/L throughout the observation period, consistently remaining above the critical threshold for shrimp survival and optimal growth, which is approximately 4 mg/L (Van Wyk & Scarpa, 1999).

During the initial phase (Days 0–23), the differences in DO levels between morning and afternoon measurements were relatively minor. However, during the later phase (Days 24–35), more pronounced fluctuations were observed, with differences ranging from 0.5 to 2 mg/L. This pattern may be attributed to increased organic matter content from uneaten feed and shrimp excretion, leading to higher microbial decomposition activity, which consumes dissolved oxygen, especially during nighttime and early morning hours (Avnimelech, 2006; Boyd, 2017).

The afternoon peaks in DO levels can be explained by increased photosynthetic activity from phytoplankton under higher light intensity, which enhances oxygen production during daylight hours (Yang et al., 2019; Rodríguez-Olague et al., 2021). Conversely, during nighttime, the absence of photosynthesis coupled with continuous respiration from shrimp, plankton, and microbial communities results in lower DO levels (Ray et al., 2011).

Despite these fluctuations, DO levels in the ponds remained consistently within the optimal range for shrimp cultivation. The venturi pump system played a key role in maintaining sufficient oxygenation through enhanced water circulation and surface aeration, preventing oxygen stratification in the pond water (Kumaran et al., 2017).

pH

The concentration of hydrogen ions (H^+) in water, reflected by the pH value, plays a crucial role in determining water quality in shrimp aquaculture systems. It directly affects nutrient availability, phytoplankton growth, shrimp respiration, and various biochemical processes in shrimp metabolism (Boyd, 2017; Furtado et al., 2015). Maintaining a stable pH is essential for optimal shrimp health and growth, as significant deviations can lead to physiological stress, reduced feed efficiency, and increased susceptibility to disease (Ray et al., 2011; Van Wyk & Scarpa, 1999).

In this study, pH measurements were conducted in the morning (6 a.m.) and afternoon (4 p.m.) (Figure 2d). The results revealed that during the early phase (Day 0–17), pH values remained relatively stable, ranging from 8.6 to 8.7. However, starting from Day 18 to Day 35, more pronounced fluctuations between morning and afternoon readings were observed, with morning pH values generally being slightly higher.

These variations can be attributed to photosynthetic activity by phytoplankton during daylight hours, which reduces CO_2 concentrations in the water, leading to an increase in pH (Hargreaves, 1998; Boyd et al., 2018). Conversely, during the night and early

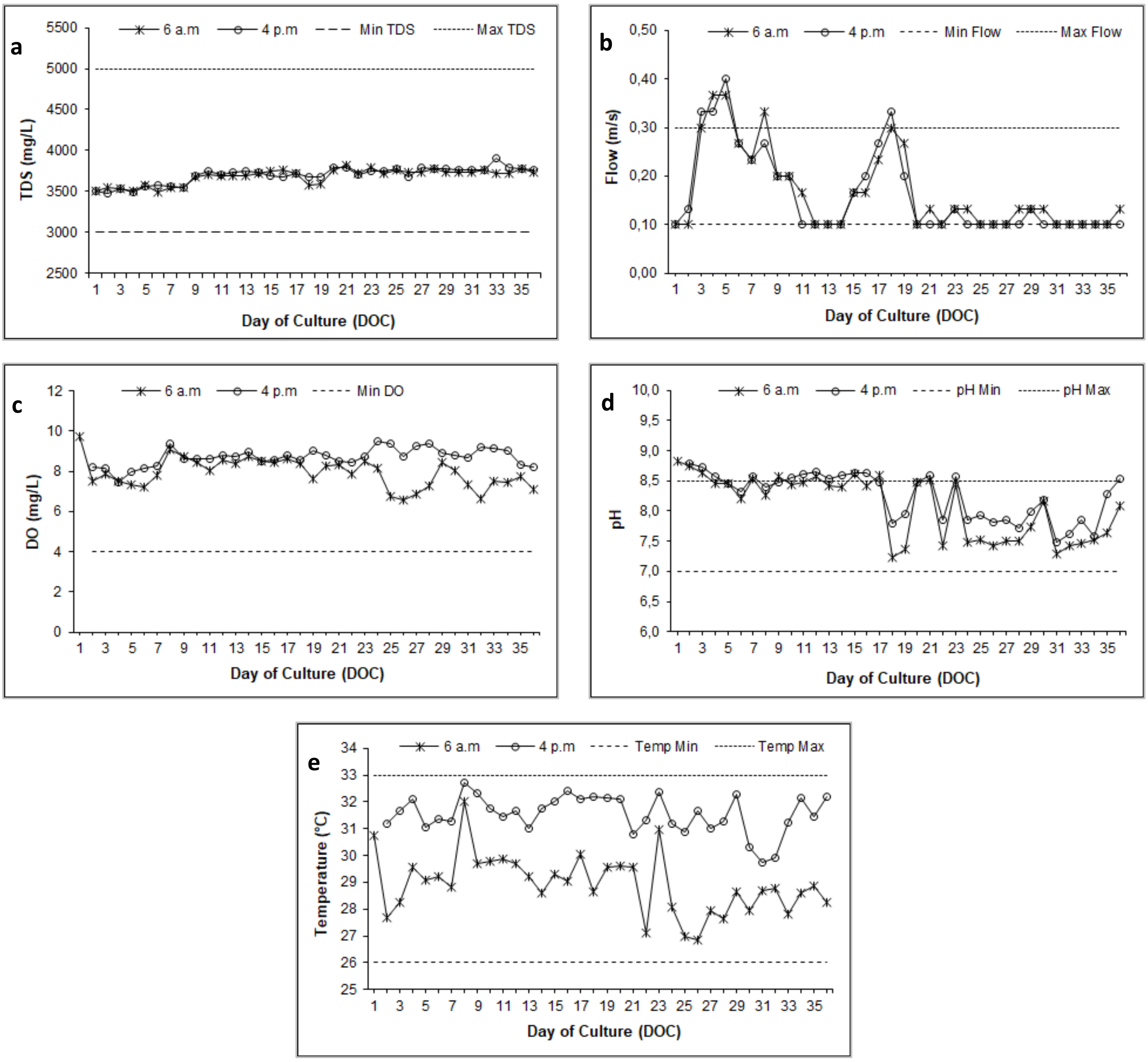

Figure 2. (a) Total dissolved solids in the white shrimp aquaculture using round ponds and venturi pump. **(b)** Water flow velocity in the white shrimp aquaculture using round ponds and venturi pump. **(c)** Dissolved oxygen in the white shrimp aquaculture using round ponds and venturi pumps. **(d)** pH in the white shrimp aquaculture using round ponds and venturi pump. **(e)** Temperature in the white shrimp aquaculture using round ponds and venturi pump.

morning, respiration from shrimp, microbes, and phytoplankton results in CO_2 accumulation, which lowers pH levels (Avnimelech, 2006). Additionally, the decomposition of organic matter from feed residues and shrimp excretion contributes to shifts in pH dynamics through microbial metabolism and ammonia production (Furtado et al., 2011).

Despite these fluctuations, the pH values in this study remained consistently within the optimal range for white shrimp growth (7.5–8.5) (Van Wyk & Scarpa, 1999; Kumar et al., 2018). This stability can be attributed to the venturi pump system, which enhances water circulation, reduces localized pH imbalances, and maintains a balanced aquatic environment (Kumaran et al., 2017).

Temperature

Water temperature is a critical parameter in white shrimp (*Litopenaeus vannamei*) cultivation, directly influencing metabolic activity, immune response, growth rate, and overall shrimp health (Kumar et al., 2018; Boyd & Tucker, 1998). Optimal temperature ranges are essential to ensure efficient feed conversion, reduce stress, and minimize susceptibility to disease (Van Wyk & Scarpa, 1999).

In this study, water temperature was measured in the morning (6 a.m.) and afternoon (4 p.m.) to capture diurnal temperature variations in circular ponds equipped with venturi pumps (Figure 2e). The results showed that morning temperatures ranged from 27 to

31°C, while afternoon temperatures increased to 30 to 32.9°C. A consistent temperature difference of 1 to 3°C was observed between morning and afternoon across the cultivation period.

This diurnal fluctuation aligns with solar radiation patterns, where daytime sunlight increases water temperature, and nighttime cooling reduces it (Furtado et al., 2011; Hargreaves, 1998). Despite these variations, the observed temperature remained within the optimal range for white shrimp growth (26–33°C) (Van Wyk & Scarpa, 1999).

The circular tank design and venturi pump system played a significant role in maintaining temperature stability. The venturi pump facilitated continuous water circulation, reducing thermal stratification and distributing heat evenly across the pond (Kumaran et al., 2017). Additionally, the circular flow dynamics helped prevent hotspots and maintained uniform temperature conditions throughout the water column.

Weekly Water Quality Parameters

Total Organic Matters

Total Organic Matter (TOM) represents the total amount of dissolved and suspended organic matter in pond water, including feed residue, shrimp excretions, and other organic particles. Proper management of TOM is crucial in shrimp aquaculture, as excessive organic matter can lead to oxygen depletion, harmful metabolite buildup, and water quality deterioration (Avnimelech, 2006; Boyd, 2017).

In this study, TOM levels were monitored throughout the cultivation period in circular tanks equipped with venturi pumps (Figure 3a). The results revealed dynamic changes in TOM concentrations over time. At the beginning of cultivation (Day 1), the TOM value was approximately 25.7 mg/L. A slight decrease was observed by Day 7 (17.1 mg/L), followed by a gradual increase, reaching 37.5 mg/L by Day 35. This pattern reflects the balance between organic matter accumulation from uneaten feed and shrimp excretion, and the decomposition facilitated by microbial activity.

The circular tank design contributes significantly to TOM management by promoting centralized waste accumulation through its sloped bottom and central drainage system. This design minimizes waste buildup in stagnant zones, allowing efficient removal of organic debris. Concurrently, the venturi pump system enhances water circulation, ensuring uniform oxygen distribution and preventing localized oxygen-depleted zones where organic matter decomposition could slow down or become anaerobic (Kumaran et al., 2017; Ray et al., 2011).

Despite the gradual increase in TOM values over time, the levels consistently remained below the critical threshold (<90 mg/L) for white shrimp cultivation (Furtado et al., 2011). This indicates that the venturi pump and circular tank system effectively support organic matter decomposition, maintaining a balanced aquatic environment conducive to shrimp health and growth.

Orthophosphate

Orthophosphate plays a crucial role in aquaculture systems as an essential nutrient for the growth of phytoplankton, microalgae, and other aquatic organisms (Boyd & Tucker, 1998; Furtado et al., 2011). These organisms form the base of the aquatic food chain, providing natural food sources for shrimp while contributing to oxygen production through photosynthesis (Hargreaves, 1998; Ray et al., 2011). However, excessive orthophosphate levels can lead to water quality deterioration, including eutrophication and excessive algal blooms, which may disrupt pond ecology and shrimp health (Avnimelech, 2006).

In this study, orthophosphate levels in circular tanks equipped with venturi pumps were monitored throughout the cultivation period (Figure 3b). The results revealed a gradual increase in orthophosphate concentrations, starting from 0.31 mg/L on Day 1 and rising steadily to 13.3 mg/L on Day 35. This increase is primarily attributed to uneaten feed residue, shrimp excretion, and microbial activity that release orthophosphate as a byproduct of organic matter decomposition (Furtado et al., 2011).

Despite exceeding the recommended threshold for shrimp cultivation (0.01 mg/L), shrimp growth remained unaffected. This resilience may be explained by the dynamic balance within the pond ecosystem, where phytoplankton and microalgae effectively utilized excess orthophosphate as a nutrient source for growth (Boyd, 2017; Yang et al., 2019). The increased phytoplankton biomass likely contributed to oxygen production and provided natural food sources for shrimp, compensating for the elevated orthophosphate levels.

The circular tank design and venturi pump system played a significant role in mitigating potential negative impacts of orthophosphate accumulation. The venturi pump's water circulation mechanism ensured even distribution of orthophosphate throughout the pond, preventing localized nutrient hotspots that could exacerbate eutrophication. Additionally, the central drainage system of the circular tanks facilitated efficient waste removal, reducing orthophosphate buildup in specific pond zones (Kumaran et al., 2017).

Nitrite

Nitrite (NO_2^-) is a toxic nitrogen compound in aquaculture systems and can have significant effects on shrimp health, growth, and overall water quality (Ciji & Akhtar, 2019; Boyd, 2017). Elevated nitrite levels can impair oxygen transport in shrimp by oxidizing hemocyanin, reducing oxygen-carrying capacity, and leading to growth retardation, reduced feed intake, and

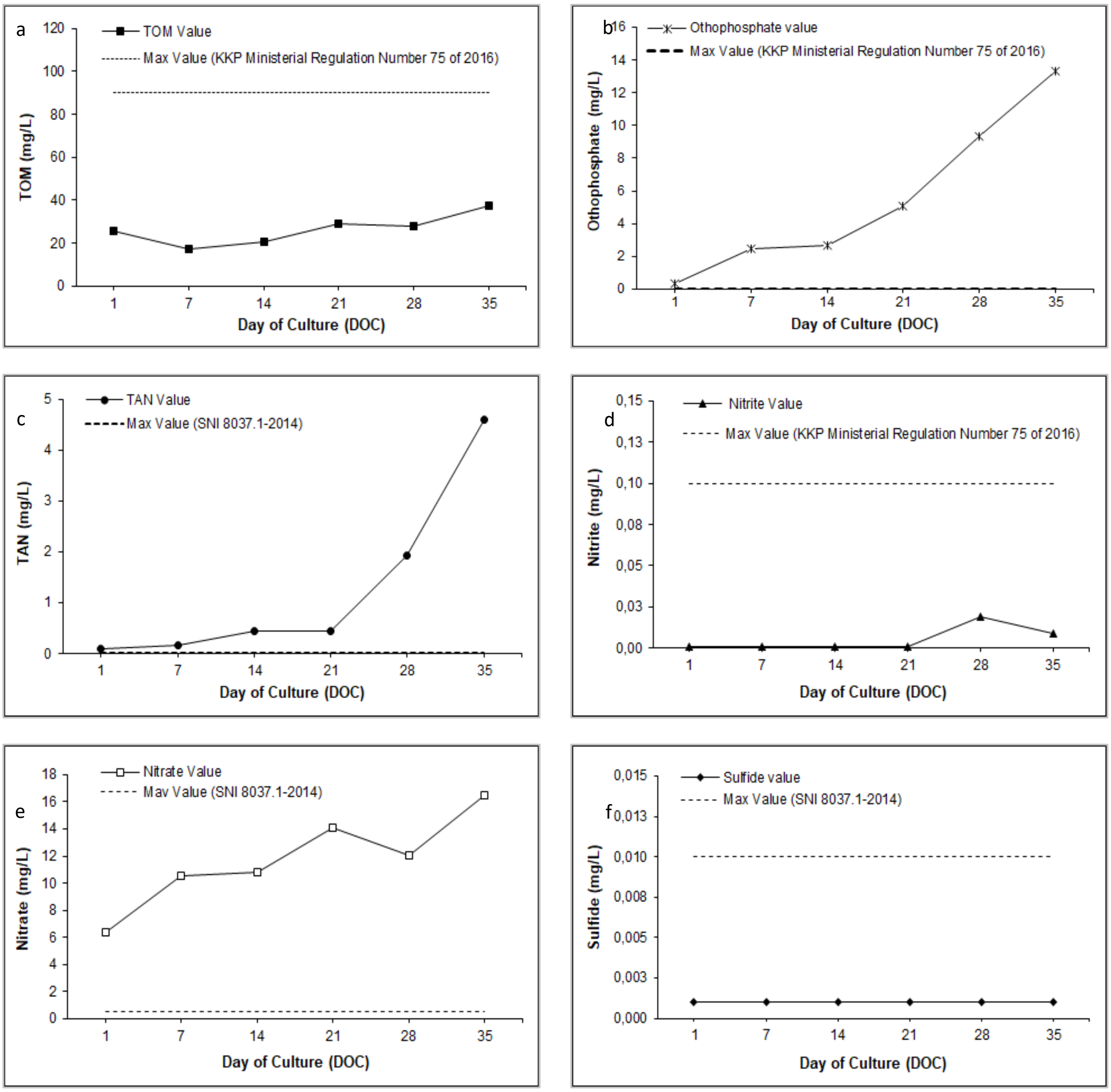

Figure 3. (a) Total organic matter in the white shrimp aquaculture using round ponds and venturi pump. **(b)** Orthophosphate in the white shrimp aquaculture using round ponds and venturi pump. **(c)** Total ammonia nitrogen in the white shrimp aquaculture using round ponds and venturi pump. **(d)** Nitrite in the white shrimp aquaculture using round ponds and venturi pump. **(e)** Nitrate in the white shrimp aquaculture using round ponds and venturi pump. **(f)** Sulfide in the white shrimp aquaculture using round ponds and venturi pump.

increased susceptibility to diseases (Furtado et al., 2011; Kuhn et al., 2010). Therefore, monitoring and managing nitrite levels are critical for maintaining water quality in shrimp aquaculture systems.

In this study, nitrite levels were monitored in circular tanks equipped with venturi pumps throughout the cultivation period (Figure 3c). The results indicate that during the initial phase (Day 1 to Day 21), nitrite concentrations remained relatively low, averaging around 0.001 mg/L. This suggests a stable nitrogen cycle in the system, where microbial nitrification effectively converted ammonia to nitrite and then to less harmful nitrate (Avnimelech, 2006).

However, on Day 28, a temporary spike in nitrite levels was observed, reaching 0.02 mg/L, before decreasing to 0.01 mg/L on Day 35. This fluctuation may be attributed to uneaten feed residue, shrimp excretions, and increased microbial activity, leading to an imbalance in the nitrification process (Kuhn et al., 2010; Ray et al., 2011). Additionally, variations in water flow dynamics caused by the shrimp's growing biomass and feed input could have temporarily altered the efficiency of nitrite conversion.

Despite this temporary spike, nitrite levels remained well below the critical threshold for shrimp health (0.1 mg/L) (Van Wyk & Scarpa, 1999; Furtado et al., 2011). This stability can be attributed to the venturi pump system, which promotes efficient water circulation and enhances aeration, supporting the growth of nitrifying bacteria responsible for converting nitrite into nitrate. Furthermore, the central drainage system of the circular tanks minimizes organic matter accumulation, reducing the potential for localized nitrite hotspots (Kumaran et al., 2017).

Total Ammonia Nitrogen

Total Ammonia Nitrogen (TAN) represents the total concentration of ammonia in water, including ionized ammonia (NH_4^+) and unionized ammonia (NH_3). While NH_4^+ is relatively non-toxic, NH_3 (unionized ammonia) is highly toxic to shrimp, even at low concentrations, as it can cause gill damage, impaired metabolism, reduced immunity, and increased mortality rates (Chang et al., 2015; Kuhn et al., 2010). Proper monitoring and management of TAN are therefore crucial in aquaculture systems to maintain optimal water quality and ensure shrimp health and productivity (Boyd, 2017; Avnimelech, 2006).

In this study, TAN levels were monitored in circular tanks equipped with venturi pumps throughout the cultivation period (Figure 3d). The results showed an initial increase in TAN values, rising from 0.1 mg/L on Day 1 to 0.4 mg/L on Day 21. This increase is primarily attributed to the excretion of metabolic waste by shrimp, unconsumed feed residues, and the microbial decomposition of organic matter (Furtado et al., 2011).

A more pronounced spike in TAN levels was observed on Days 28 and 35, reaching 1.9 mg/L and 4.6 mg/L, respectively. These sharp increases suggest an imbalance in the ammonia-nitrification cycle, where ammonia production exceeded the capacity of nitrifying bacteria to convert TAN into less harmful nitrite (NO_2^-) and nitrate (NO_3^-) (Kuhn et al., 2010; Ray et al., 2011). This imbalance could be linked to increased shrimp biomass, elevated feeding rates, and organic matter accumulation over time.

Despite these increases, the venturi pump system played an important role in mitigating the adverse effects of elevated TAN levels. The enhanced water circulation and aeration provided by the venturi system improved oxygen availability, which is essential for nitrifying bacteria (Nitrosomonas spp. and Nitrobacter spp.) to efficiently convert TAN into nitrate (Boyd & Tucker, 1998; Kumaran et al., 2017). Furthermore, the central drainage system of circular tanks helped prevent localized ammonia hotspots by removing sedimented waste efficiently.

Nevertheless, TAN concentrations observed in this study exceeded the recommended threshold for shrimp health (<0.01 mg/L) (Van Wyk & Scarpa, 1999). While shrimp growth was not critically affected, these elevated levels highlight the importance of routine monitoring, efficient feeding practices, and regular water exchange to prevent TAN accumulation.

Nitrate

Nitrate (NO_3^-) is the final product of the nitrification process, where ammonia (NH_3/NH_4^+) is sequentially converted into nitrite (NO_2^-) and then into nitrate by nitrifying bacteria (Nitrosomonas spp. and Nitrobacter spp.) (Avnimelech, 2006; Boyd, 2017). While nitrate is significantly less toxic than ammonia and nitrite, elevated concentrations can negatively affect shrimp health, growth, and overall water quality (Furtado et al., 2011; Kuhn et al., 2010). Prolonged exposure to high nitrate levels can reduce shrimp feed intake, suppress growth rates, and compromise immune responses (Ciji & Akhtar, 2019; Ray et al., 2011).

In this study, nitrate concentrations in circular tanks equipped with venturi pumps were monitored throughout the cultivation period (Figure 3e). The results showed a steady increase in nitrate levels, starting from 6.4 mg/L on Day 1 to 10.8 mg/L on Day 14, 14.8 mg/L on Day 21, and peaking at 17.4 mg/L on Day 35. These concentrations consistently exceeded the recommended threshold for shrimp health (0.5 mg/L) (Van Wyk & Scarpa, 1999).

The gradual rise in nitrate levels can be primarily attributed to excess feed residue, shrimp excretion, and microbial decomposition of organic matter, all of which contribute to increased nitrogenous waste in the water (Furtado et al., 2011; Ray et al., 2011). The nitrification process in well-aerated systems efficiently converts ammonia and nitrite into nitrate, but without adequate water exchange or denitrification processes, nitrate can accumulate to suboptimal levels.

The venturi pump system played a significant role in mitigating excessive nitrate accumulation by enhancing water circulation and oxygenation. Improved water flow supports the distribution of nitrifying bacteria throughout the pond, optimizing ammonia and nitrite conversion into nitrate (Kumaran et al., 2017). Additionally, the circular tank design with a central drainage system facilitates efficient organic waste removal, reducing excess organic matter that could further contribute to nitrate buildup.

Despite these mitigating factors, the continuous accumulation of nitrate observed in this study underscores the importance of regular water exchange, effective waste management, and potentially integrating denitrification systems (Avnimelech, 2006; Boyd, 2017). These strategies are essential for maintaining nitrate levels within safe limits, ensuring an environment conducive to shrimp health, growth, and overall aquaculture sustainability.

Sulfide

Sulfide (H_2S) is a toxic compound in aquaculture systems, primarily formed under anaerobic conditions through the microbial decomposition of organic matter in oxygen-depleted pond sediments (Boyd, 2017; Furtado et al., 2011). Even at low concentrations, sulfide can impair shrimp respiratory function, damage gill tissues, reduce feed intake, and lead to mortality (Chen & Chen, 2006; Kuhn et al., 2010). Therefore, maintaining sulfide levels below toxic thresholds is essential for successful shrimp cultivation.

In this study, sulfide concentrations were monitored in circular tanks equipped with venturi pumps throughout the cultivation period (Figure 3f). The results revealed that sulfide levels remained consistently low at approximately 0.001 mg/L from Day 0 to Day 35. These values are well below the critical threshold for white shrimp survival and growth, indicating effective sulfide control within the system (Van Wyk & Scarpa, 1999).

The circular tank design and venturi pump system played a crucial role in maintaining low sulfide levels. The continuous water circulation provided by the venturi pump prevented the formation of anaerobic zones in the pond, where sulfide accumulation typically occurs (Avnimelech, 2006; Kumaran et al., 2017). Additionally, the central drainage system of the circular tanks facilitated efficient removal of organic matter and sediment, minimizing the organic load available for sulfate-reducing bacteria, which are primarily responsible for sulfide production (Furtado et al., 2011).

Moreover, the enhanced oxygen distribution from the venturi pump created a more aerobic environment, which suppresses the activity of sulfate-reducing bacteria (Hargreaves, 1998; Boyd & Tucker, 1998). As a result, the sulfide content remained stable and within safe limits throughout the blind feeding phase.

These findings highlight the synergistic effect of circular tank design and venturi pump systems in preventing sulfide accumulation and ensuring optimal water quality conditions. Effective water circulation, oxygenation, and waste removal mechanisms in this system significantly reduce the risk of sulfide toxicity, creating a stable aquatic environment conducive to shrimp health and growth.

Shrimp Growth

Shrimp growth is a critical parameter for evaluating the performance and efficiency of aquaculture systems, particularly in circular tanks equipped with venturi pumps during the blind feeding phase. Growth performance serves as a benchmark for assessing the system's ability to maintain optimal environmental conditions, including water quality, nutrient availability, and waste management (Boyd & McNevin, 2021; Boyd, 2017).

In this study, shrimp growth was evaluated using two primary parameters: Average Body Weight (ABW) and Average Daily Growth (ADG). ABW provides an estimate of the average size of individual shrimp at specific time points, while ADG reflects the daily weight gain rate and serves as an indicator of growth efficiency (Kumar et al., 2018; Moss et al., 2001).

Average Body Weight

Average Body Weight (ABW) is a key indicator of shrimp growth performance and cultivation success, reflecting the effectiveness of water quality management, feeding practices, and environmental stability (Boyd, 2017; Moss et al., 2001). In aquaculture systems, achieving or exceeding growth standards serves as a benchmark for evaluating the suitability of the applied cultivation methods.

In this study, ABW was monitored in circular tanks equipped with venturi pumps during the blind feeding phase (Figure 4a). The initial ABW value was recorded at approximately 0.01 grams and increased steadily to 3.1 grams by Day 30. This value aligns with the Indonesian National Standard (SNI) for shrimp growth, which recommends an average body weight of 3 grams on Day 30 (SNI 01-7246-2006).

Subsequently, ABW continued to increase, reaching 5.2 grams on Day 37 and slightly rising to 5.4 grams by the end of the observation period. These values exceed the SNI standard (4.17 grams), indicating that shrimp growth in the circular tank-venturi pump system was not only sufficient but also surpassed expected benchmarks.

The circular tank design, with its central drainage system, effectively prevents organic waste buildup and maintains water clarity. Additionally, the venturi pump system ensures optimal water circulation and oxygen distribution, creating a stable and controlled aquatic environment that supports efficient nutrient absorption and metabolic processes (Ray et al., 2011; Kumaran et al., 2017).

The consistent ABW results suggest that the integration of circular tank systems and venturi pumps provides an optimal habitat for shrimp growth, minimizing environmental stressors and ensuring efficient feed utilization. These findings confirm that this system is a viable and effective approach for supporting shrimp growth during the blind feeding phase, contributing to improved productivity and economic feasibility in aquaculture practices.

Average Daily Growth

Average Daily Growth (ADG) is a key parameter for evaluating the growth efficiency and health status of shrimp in aquaculture systems. It reflects how effectively shrimp utilize feed and environmental resources to support daily weight gain, serving as a benchmark for assessing the performance of cultivation systems (Boyd, 2017; Kumar et al., 2018).

In this study, ADG was monitored in circular tanks equipped with venturi pumps during the blind feeding phase (Figure 4b). The results showed a positive growth trend, with ADG increasing from 0.1 grams/day on Day 30 to 0.31 grams/day on Day 37. This consistent growth pattern suggests that the shrimp were able to effectively metabolize nutrients from the provided feed, supported by stable environmental conditions facilitated by the circular tank and venturi pump system (Moss et al., 2001; Ray et al., 2011).

The circular tank design ensured uniform water circulation and waste removal, reducing localized stressors that could impede growth. The venturi pump system further enhanced oxygen distribution, supporting efficient feed conversion and reducing physiological stress on shrimp (Kumaran et al., 2017; Furtado et al., 2011). Additionally, the central drainage system minimized organic waste buildup, preventing the deterioration of water quality that could hinder growth (Avnimelech, 2006).

The observed ADG values exceeded typical growth expectations for shrimp cultivation systems during the blind feeding phase, indicating a well-balanced interaction between feed quality, water quality management, and environmental stability (SNI 01-7246-2006). These results demonstrate that the circular tank and venturi pump system provided an optimal aquatic environment for white shrimp growth, supporting efficient nutrient uptake and metabolic activity. The steady increase in ADG throughout the blind feeding phase highlights the effectiveness of circular tanks and venturi pumps in creating an environment conducive to consistent and healthy shrimp growth, aligning with cultivation standards and supporting the sustainability of white shrimp farming operations.

Conclusion

This study demonstrates that the integration of circular pond systems with venturi pumps provides a favorable and controlled environment for cultivating white shrimp (*Litopenaeus vannamei*), particularly during the blind feeding phase. The system effectively maintained key water quality parameters, including total dissolved solids, water flow velocity, dissolved oxygen, pH, temperature, total organic matter, nitrite, total ammonia nitrogen, and sulfide levels, all within ranges suitable for shrimp health and growth. These stable conditions directly supported shrimp development, as evidenced by the Average Body Weight (ABW) and Average Daily Growth (ADG) values meeting or exceeding Indonesian National Standards (SNI) benchmarks.

The circular pond design ensured efficient waste removal and minimal organic matter buildup through its central drainage system, while the venturi pump system enhanced oxygen distribution and water circulation, preventing the formation of anaerobic zones and localized nutrient imbalances. These design features contributed to maintaining water quality stability and mitigating the accumulation of harmful compounds such as sulfide, ammonia, and nitrite.

However, elevated levels of orthophosphate and nitrate were observed, exceeding ideal thresholds for shrimp cultivation. While these did not appear to negatively affect shrimp growth within the scope of this study, they highlight the need for improved nutrient management practices and periodic water exchange to prevent long-term environmental impacts.

The integration of circular pond systems with venturi pumps proves to be an effective, scalable, and sustainable aquaculture approach for white shrimp cultivation. This system not only enhances water quality management and shrimp growth performance but also addresses challenges associated with space and resource limitations in shrimp farming. Future research should focus on refining nutrient management strategies and exploring the long-term effects of elevated orthophosphate and nitrate levels to further optimize this innovative aquaculture system for maximum productivity and environmental sustainability.

Ethical Statement

The authors declare that no ethical approval is required.

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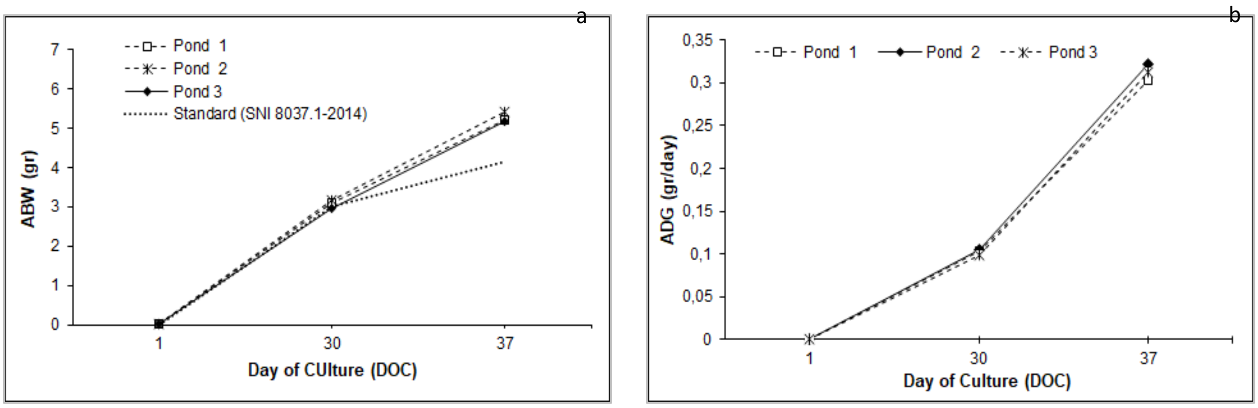

Figure 4. (a) Average Body Weight (ABW) of the white shrimp in round ponds and venturi pump. **(b)** Average Daily Growth (ADG) of the white shrimp in round ponds and venturi pump.

Author Contribution

AK: Conceptualization, Investigation, Data curation, Formal analysis, Methodology, Writing – review & editing, Funding acquisition, Project administration, Resources; AAA: Investigation, Data curation, Formal analysis, Methodology; ZP: Investigation, Data curation, Formal analysis, Methodology; YADS: Investigation, Data curation, Formal analysis, Methodology; IMAZ: Formal analysis, Writing – review & editing; KSM: Investigation, Data curation, Formal analysis, Methodology; TBP: Conceptualization, Methodology.

Conflict of Interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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