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Research article

Numerical simulation study of flow patterns in shrimp pond due to aerator layout for shrimp harvesting machine application

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Abstract

Importance of the work: Efficient shrimp harvesting may be enhanced using a centrifugal force technique for aerator placement optimization in Pacific white shrimp ponds.
Objectives: To examine the influence of diverse aerator layouts on shrimp harvesting efficiency in the specified ponds.
Materials & Methods: Three prevalent aerator layouts were examined: Type A (4-spiral and 4-wheeled paddle aerators), Type B (4 cross-shaped middle cages), and Type C (4 15-wheeled paddle aerators). The velocity and sediment aggregation efficiency were analyzed using the SolidWorks Flow Simulation software and a drop particle function. Model accuracy was validated by comparing actual water velocity measurements with the simulation results.
Results: The analysis presented a strong concurrence between the real and simulated data, substantiating the precision of the simulation model in replicating the water flow characteristics in the investigated shrimp pond layouts. The highest water velocity of 21.396 cm/s was produced by the Type C aerator layout positioned at 0.5 m below the water surface, whereas the Type A layout, situated at 1.5 m depth, produced the lowest water velocity of 0.978 cm/s. The particle study revealed the superior particle collection efficiency of Type C, reaching 91% and surpassing the other layouts. These findings emphasized the significant of the aerator's location within the pond, with the Type C layout being the most effective in terms of water flow and particle collection.
Main finding: This research highlighted the importance of optimizing aerator layouts in Pacific white shrimp ponds for improved water circulation dynamics and enhanced shrimp harvesting efficiency. The Type C layout achieved the highest practical collection efficiency of 91%, contributing to sustainable aquaculture practices.

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Introduction

In the realm of aquaculture, the cultivation of Pacific white shrimp (*Litopenaeus vannamei*) has witnessed remarkable technological advancements and refined methodologies. However, the domain of shrimp harvesting remains less developed, with the present average capacity for Pacific white shrimp harvest standing at 1 t/hr (Thoetrattanakia and Sangpradit, 2022). The authors reported that a pipeline system could effectively transport shrimp over distances of up to 360 m while maintaining their quality. The exploration of numerical and computational fluid dynamics (CFD) models has been extensive in predicting and optimizing fluid flow within shrimp ponds. For example, Kang et al. (2004) created a 3D numerical model to simulate flow in shrimp ponds, successfully corroborating its accuracy with field data and precisely forecasting water velocity and flow patterns. Likewise, Zhang et al. (2022) used a CFD model to investigate the influence of pond layout and entrance structures on shrimp flow patterns and growth. Their work illustrated that the design of the inlet could optimize flow patterns and enhance shrimp growth. Additionally, research conducted by Liu et al. (2017) delved into this field.

The utilization of simulation models transcends the scope of flow optimization. Wang et al. (2022) directed their attention toward water quality control and feed management, applying a 3D hydrodynamic model to anticipate the repercussions of water exchange rates. In another example, Ruiz-Velazco et al. (2010) formulated a model that incorporated environmental variables relevant to shrimp ponds. Roversi et al. (2020) applied a numerical model to evaluate the influence of fluctuations in currents. Contributions to this field have also been made by Lotz and Soto (2002). Thus, simulation models have evolved into indispensable tools for the management of shrimp ponds, enabling accurate predictions of shrimp growth and disease control. Taparhudee (2002) used Flow Simulation to solve the Navier-Stokes equations within fluid regions, which serve as foundational equations (Sobachkin et al., 2014).

Hence, the aim of the current study was to examine and rectify the inadequate harvesting process in Pacific white shrimp farming. The research endeavored to use simulation models to enhance aerator layouts and the overall effectiveness of the shrimp harvesting procedure.

Materials and Methods

The experimental site was in Praneet subdistrict, Khao Saming district, Trat province, Thailand (12.445239104012108N, 102.33619210240366E). The study involved comparing the effects of three types of surface aerators (spiral, 15-propeller wheeled and 4-blade wheeled) in a closed system shrimp farm. A combination of surface aerators and three arrangement types was considered. Pacific white shrimp (28 pieces/kg and 250,000 shrimp/pond) were cultured for 67 d in ponds with dimensions of 46 m with, 46 m length and 1.7–1.8 m depth (Fig. 1). Water velocity measurements were taken every 3 m from the aerator at depths of 0.5 m, 1 m and 1.5 m to ascertain actual usage conditions.

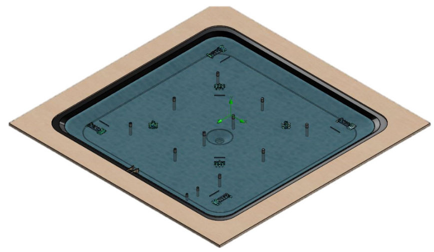

Fig. 1 illustrates a general diagram of the shrimp pond. The middle figure highlights the sediment collection point's location within the pond and also depicts the placement of support pillars for the roof structure

The primary measuring tools used were: a flow probe (Global Water Instruments; model FP211 Serial 1832002269; USA), a laser distance measurer (Bosch; GLM 250 VF Professional Serial GLM 250 VF 3601 K72 170; Germany) and the SolidWorks Premium software (2019 SP01 Flow Professional; Serial No. 9000 0119 3109 0543 H87B FQB8; France). The aerators (KSP Equipment Thailand) consisted of: a paddlewheel spiral aerator (Fig. 2A), a paddle aerator with 15 wheels (Fig. 2B) and a paddle aerator with 4 wheels (Fig. 2C).

Fig. 2 Paddlewheel types: (A) spiral aerator; (B) 15-wheeled aerator; (C) 4-wheeled aerator

Experiment setup

Step 1, Aerator placement: The three types of water surface aerator (spiral aerator, 15-wheeled paddle aerator and a 4-wheeled paddle aerator) were placed in the pond as shown in the layouts (Type A, Type B and Type C) in Figs. 3A–3C, respectively.

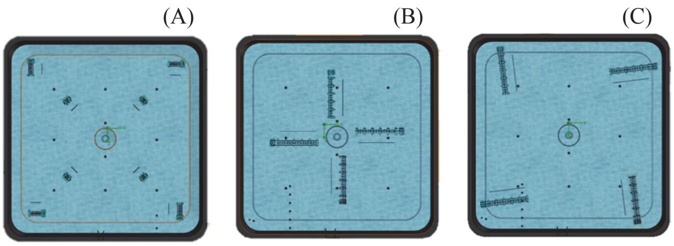

Fig. 3 Paddle wheel positions: (A) layout A; (B) layout B; (C) layout C

Step 2, Water velocity measurement: The water velocity measurement apparatus was used to evaluate the water velocity at specific points in the pond. The water velocity in the water was measured every 3 m from the aerator at depths of 0.5 m, 1.0 m and 1.5 m below the surface.

Step 3, Calibration and simulation setup: The initial measurement data acquired from the actual pond conditions were calibrated for precision and input into the SolidWorks Flow Simulation software for detailed analysis.

Step 4, Numerical simulation and model verification: The simulation model was developed using the SolidWorks software.

Step 5, Particle study via SolidWorks Flow Simulation: The particle study feature within the SolidWorks software was utilized to introduce 100 particles into the shrimp pond model to investigate aggregation behavior at the pond's center and to assess suction effects.

Numerical simulation method

The simulation was executed using the SolidWorks software, with a specific focus on the grid domain and visualization (Figs. 4A–4C). Comprehensive details about the cell count utilized in the simulation are available in Table 1. The simulation analysis yielded crucial data, encompassing water flow patterns under diverse conditions and physical parameters. The presence and behavior of shrimp in the pond were taken into account. The research scrutinized the movement and behavior of the water and shrimp at varying locations in the shrimp ponds (Figs. 5–7 and 11A–11C), as outlined in Table 1.

Table 1 Geometrical parameters for shrimp pond aerator layouts

Aerator layout	Fluid cells	Solid cells	Partial cells	Total cells
A	106,602	113,594	63,597	106,602
B	200,347	173,543	85,829	200,347
C	172,920	170,375	81,650	172,920

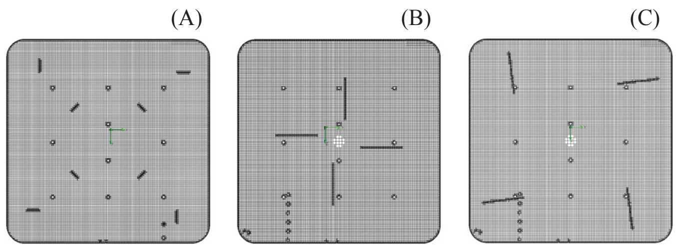

Fig. 4 Grids of computational simulation domain shrimp pond aerator layouts: (A) layout A; (B) layout B; (C) layout C

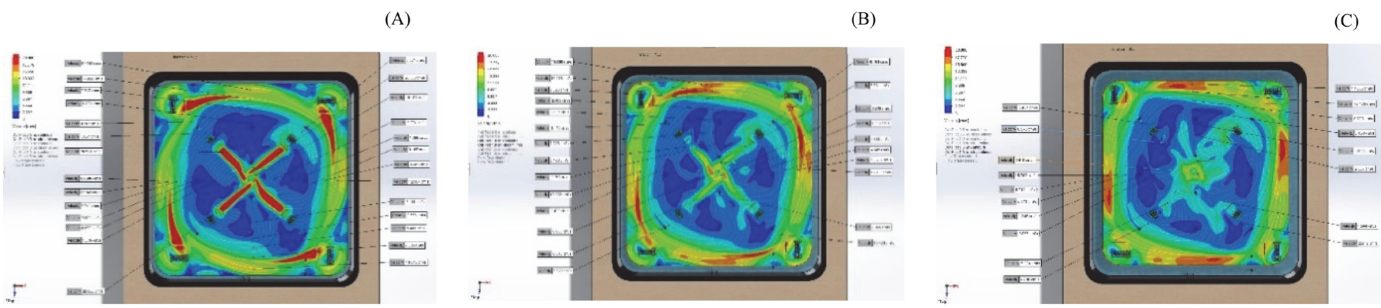

Fig. 5 Aerator layout A: (A) water depth 0.5 m; (B) water depth 1 m; (C) water depth 1.5 m

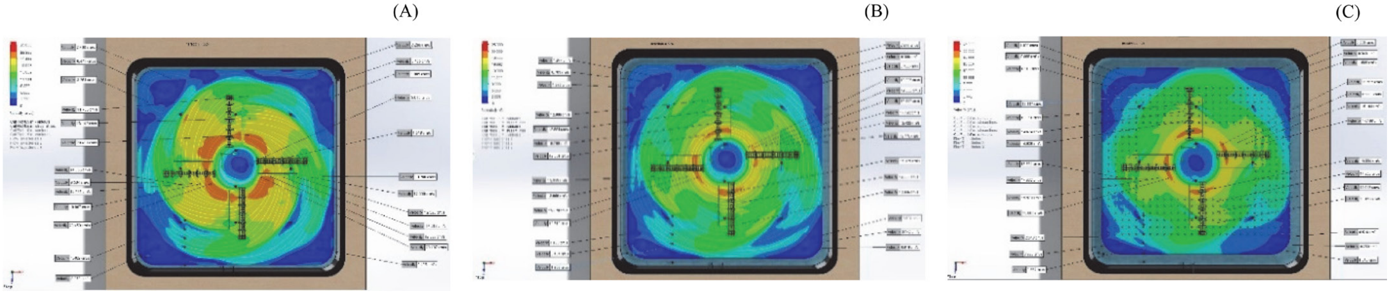

Fig. 6 Aerator layout B: (A) water depth 0.5 m; (B) water depth 1 m; (C) water depth 1.5 m

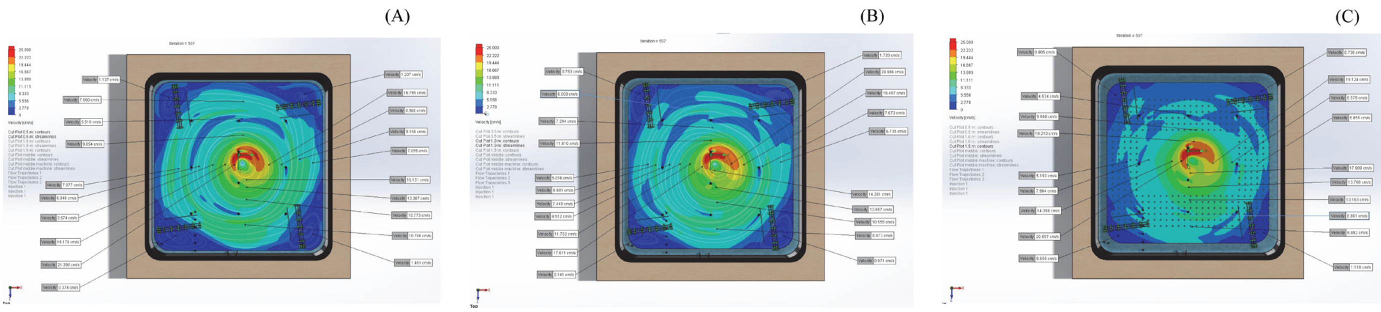

Fig. 7 Aerator layout C: (A) water depth 0.5 m; (B) water depth 1 m; (C) water depth 1.5 m

SolidWorks Flow Simulation particle study function

The particle study functionality within SolidWorks Flow Simulation is a valuable instrument for evaluating sediment and waste management in shrimp ponds. This tool helps with the simulation of suspended solids and waste particle mobility in the ponds. By modeling particle dynamics, researchers acquire valuable understanding of sedimentation patterns and waste accumulation. Furthermore, the particle study function can predict sedimentation patterns and evaluated suspended solid deposition on the pond bottom (Figs. 8A–8C).

Centrifugal force in a bladeless shrimp harvester concept

The study investigated improving Pacific white shrimp harvesting efficiency through sludge collection and aerator

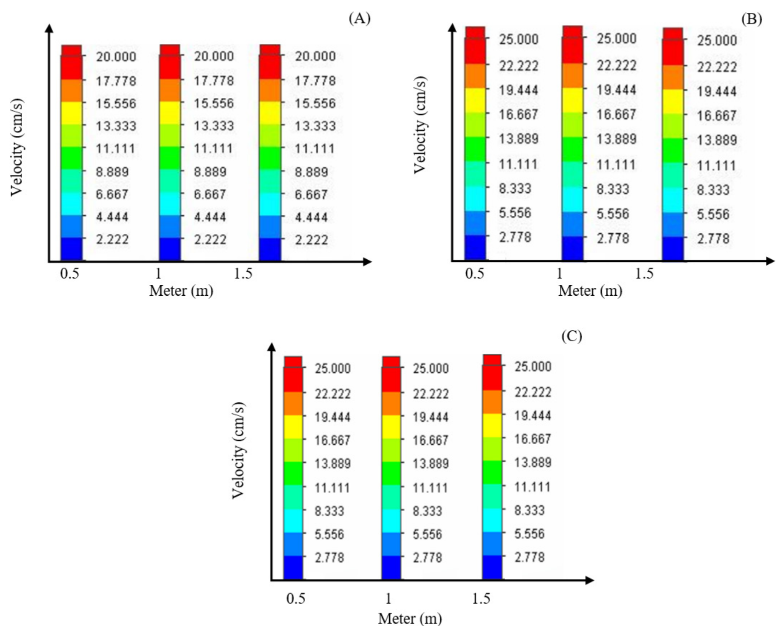

Fig. 8 Color bar velocity simulation for water depths of 0.5 m, 1 m and 1.5 m for: (A) aerator layout A; (B) aerator layout B; (C) aerator layout C

layout optimization. This involved investigation into the sludge retention capability of Pacific white shrimp ponds, while simultaneously accounting for the influence of the aerator placement layout on the water surface. By comprehending and optimizing these factors, the overall efficacy of shrimp harvesting should be substantially elevated. The core objective of this research revolved around the conception and elucidation of the centrifugal force phenomena in a bladeless shrimp harvester. A fundamental understanding of centrifugal force is pivotal to fully comprehend this concept, as defined in Equation 1:

$$H = \frac{(P_{dis} - P_{su})}{\rho g} + \frac{(V_{dis}^2 - V_{su}^2)}{2g} + Z_{dis} - Z_{su} \quad (1)$$

where H is the pump head; P_{dis} is the pressure at the discharge; P_{su} is the pressure at the suction; ρ is the fluid density; g is acceleration due to gravity; V_{dis} is the velocity at the discharge; V_{su} is the velocity at the suction; Z_{dis} is the elevation at the discharge; and Z_{su} is the elevation of the suction.

The power output of a turbine can be determined using Equation 2:

$$P_{out} = \dot{m} \cdot H \cdot \eta_{turb} \quad (2)$$

where P_{out} is the turbine power output; $\dot{m}$ is the mass flow rate; H is the head developed by the turbine; and η_{turb} is the turbine efficiency.

Enhancing the stability, efficiency and operational lifespan of centrifugal pumps is imperative to achieve heightened energy efficiency and for alignment with global carbon neutrality goals (Cong et al., 2015; Pei et al., 2017). Extensive research efforts have been devoted to investigating the correlation between energy dissipation and entropy generation in fluid machinery, yielding valuable insights into the optimization of pump performance (Jiang et al., 2011; Fan et al., 2022; Lai et al., 2022; Zhang and Tang, 2022).

Aerator type

In brief, the technical specifications for all three water surface aerator models are: 1) spiral aerator—width 2.754 m, impeller speed 120 revolutions per minute (rpm) and 2.2 kW motor (Fig. 2A); 2) 15-wheeled paddle aerator—frontal width 12 m, propeller speed 75 rpm for water impact and 2.2 kW motor (Fig. 2B); 3) 4-wheeled paddle aerator—front width 2 m, 100 rpm and 1.4 kW motor (Fig. 2C).

Aerator position layout

The three studied varieties of aerator have gained substantial popularity and are utilized across various applications. Generally, they are positioned within Pacific white shrimp ponds based on the insight and expertise of the individual shrimp farmers. This positioning is informed by observations of shrimp feces sediment suction, shrimp growth rates and water quality during farming that are incorporated with practical know-how. Successful shrimp farming hinges upon numerous factors, with aerator arrangement being a pivotal contributor. Despite its importance, there has been no reported comprehensive study applying a systematic flow simulation model to assess sludge removal efficiency from ponds. The current study addressed this based on the designated pattern, incorporating the three layouts for comparative analysis. The specific objective was to determine the effectiveness of extracting substances from the pond bottom, precisely at the drainage hole situated at the pond's central point. Three layouts, denoted as Type A, B, and C, were developed to enable a comparative analysis.

Type A involves positioning four spiral aerators at the corners of the shrimp pond, directly facing the aerators. Additionally, four 4-wheeled surface aerators are strategically situated around an inner circle, oriented toward the central region of the shrimp pond (Fig. 3A). The spiral surface aerators function to gather shrimp manure sludge, directing it towards the pond's center. Upon reaching the central point, the 4-wheeled surface aerators collect the shrimp manure sediment, channeling it to the designated shrimp manure collection opening for subsequent extraction. This process involves suctioning the sediment and removing it through the central drainage hole of the shrimp pond.

Type B involves a configuration with four 15-wheeled paddle aerators (Fig. 3B). These aerators are positioned at a distance from the center of the shrimp pond, arranged in a clockwise manner with the front of the aerator equipment defined as the direction in which the water velocity flows from the aerator. The rationale behind this specific arrangement is to expedite the collection of sediment in the central area of the shrimp pond by utilizing the swiftness of incoming water. It is anticipated that this increased water velocity will lead to an enhancement in the sedimentation rate.

Type C uses four 15-wheeled paddle aerators, positioned in each of the pond's corners (Fig. 3C). This paddle wheel type is anticipated to generate elevated velocity at the pond's outer corners, inducing a swirling motion at the center, promoting the overall removal of shrimp excrement throughout the pond.

Measurement

Aerator placement and water velocity measurement

During this step, meticulous installation of the water surface aerators was undertaken following aerator layout A within the Pacific white shrimp pond (Fig. 3A). The arrangement encompasses two distinct aerator types: spiral aerators (Fig. 2A) and 4-wheeled surface aerators (Fig. 2C). The spiral aerators, acknowledged for their effective water circulation attributes, were strategically positioned at the pond's corners. This positioning generates a swirling water current, facilitating the gathering of shrimp manure sludge towards the pond's center.

In conjunction with the spiral aerators, the placement of the 4-wheeled surface aerators was deliberately along the inner circle, oriented towards the pond's central zone. These aerators were custom-designed to optimize the accumulation of shrimp manure sediment and streamline its conveyance towards the shrimp manure collection point, where suction occurred. For precision, the water velocity measurements in the Pacific white shrimp pond were meticulously recorded using the reliable, high precision Global Water Instruments model FP211 (Figs. 10A–10C and 11A), as the water velocity measurement instrument. The measurement locations were accurately located 3 m from the aerator's face to capture essential data.

The water velocity readings were captured at regular 3 m intervals from the aerator, with measurement positions at 3 m, 6 m, 9 m, 12 m, 15 m, 18 m, 21 m and 24 m from the aerator (Figs. 10A–10C). Readings were taken at 0.5 m, 1.0 m and 1.5 m below the water surface and the velocities were recorded in centimeters per second (Fig. 11A). This cross-sectional measurement was expected to provide comprehensive insights into the water flow dynamics at various depths within the pond (Table 2).

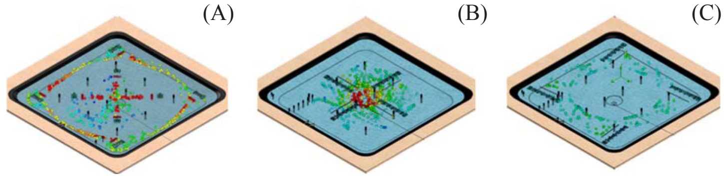

Fig. 9 Simulation of added particles: (A) aerator layout A; (B) aerator layout B; (C) aerator layout C

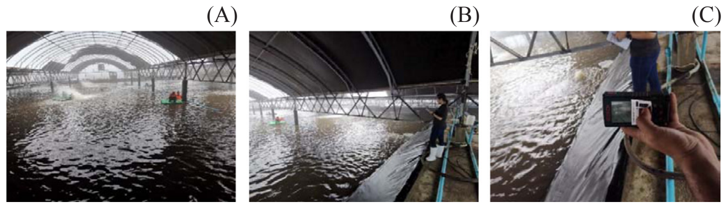

Fig. 10 Actual data collection: (A) Shows individuals measuring water velocity at various points in a shrimp pond using the Global Water Instruments model FP211; (B) Depicts the positioning of measurement points and records the measured values; (C) Illustrates the setup of measurement positions using the Bosch laser distance measurer model GLM 250 VF Professional

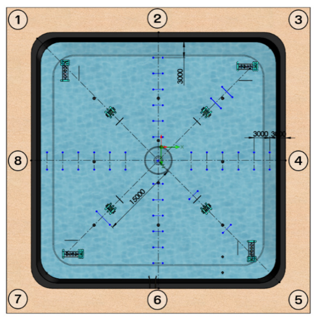

Fig. 11 Measurements points 1–8 for shrimp pond aerator layout A

Table 2 Velocity measurements for shrimp pond aerator layout A

Depth (m)	0.5	1.0	1.5	0.5	1.0	1.5	0.5	1.0	1.5	0.5	1.0	1.5
Distance (m)	Position 1 (cm/s)			Position 2 (cm/s)			Position 3 (cm/s)			Position 4 (cm/s)		
3	Aerator	Aerator	Aerator	9.14	6.10	0.00	Aerator	Aerator	Aerator	18.29	18.29	0.00
6	Aerator	Aerator	Aerator	18.29	6.10	0.00	Aerator	Aerator	Aerator	18.29	15.24	6.10
9	Aerator	Aerator	Aerator	6.10	6.10	0.00	Aerator	Aerator	Aerator	12.19	9.14	6.10
12	3.05	3.05	0.00	6.10	0.00	0.00	3.05	3.05	0.00	3.05	9.14	6.10
15	12.19	6.10	6.10	15.24	12.19	0.00	12.19	6.10	6.10	12.19	6.10	6.10
18	Aerator	Aerator	Aerator	36.58	27.43	18.29	Aerator	Aerator	Aerator	30.48	12.19	3.05
Distance (m)	Position No. 5 (cm/s)			Position No.6 (cm/s)			Position No.7 (cm/s)			Position No.8 (cm/s)		
3	Aerator	Aerator	Aerator	15.24	12.19	6.10	Aerator	Aerator	Aerator	9.14	6.10	6.10
6	Aerator	Aerator	Aerator	18.29	6.10	6.10	Aerator	Aerator	Aerator	18.29	12.19	9.14
9	Aerator	Aerator	Aerator	9.14	6.10	6.10	Aerator	Aerator	Aerator	12.19	12.19	6.10
12	12.19	6.10	3.05	6.10	3.05	3.05	Aerator	Aerator	Aerator	12.19	12.19	9.14
15	30.48	12.19	6.10	3.05	24.38	12.19	3.05	0.00	0.00	12.19	9.14	9.14
18	Aerator	Aerator	Aerator	6.10	9.14	3.05	Aerator	Aerator	Aerator	24.38	18.29	12.19

SolidWorks parameter settings for simulating water flow in shrimp ponds

The SolidWorks Flow Simulation for numerical simulations offers valuable hydrodynamic insights into shrimp ponds, especially optimizing aerator layouts to elevate the efficiency of shrimp harvesting. The key parameter settings within SolidWorks to simulate water flow within shrimp ponds of layouts A were: geometry, 3D; boundary conditions: mesh settings; and turbulence model, solver settings. The parameter configurations (see Fig. 3A) provided important hydrodynamic insights pertinent to shrimp ponds (refer to Table 3).

Verification of simulation model (water velocity) and analysis of variance

To optimize the accuracy of the analysis of variance (ANOVA), locations near the surface aerator were removed. The analysis was best conducted using positions 2, 4, 6 and 8, according to the recommendations. (Table 4). The simulation model for the shrimp pond aerator layout A was verified using a comparison of water velocity measurements between real data (Table 4) and the simulation results. The analysis demonstrated a high level of agreement between the real and simulated data, affirming the accuracy of the simulation model in replicating water flow characteristics.

Table 3 Parameter settings for SolidWorks Flow Simulation

Geometry: 3D pond geometry and components	Parameter
1. Fluid Properties:	
- Density	999.79 kg/m³
- Viscosity	0.0017912 Pa·s
- Thermal conductivity	0.56104 W/(m·K)
- Specific heat	4219.9 J/(kg·K)
2. Boundary Conditions: aerator layout A	
- Inlet:	
- velocity spiral aerator	40 cm/s
- velocity 4-wheeled paddle aerator	38 cm/s
- Temperature	273.16 K
- Environment pressure	101.32 kPa
3. Boundary Conditions: aerator layout B	
- Inlet:	
- velocity 15 wheeled paddle aerator	35 cm/s
- Temperature	273.16 K
- Environment pressure	101.32 kPa
4. Boundary Conditions: aerator layout C	
- Inlet:	
- velocity 15-wheeled paddle aerator	35 cm/s
- Temperature	273.16 K
- Environment pressure	101.32 kPa

Table 4 Simulated and actual water velocity measurements for shrimp pond aerator layout A at different positions from aerator

Distance from Aerator (m)	Position 2 (cm/s)			Position 4 (cm/s)			Position 6 (cm/s)			Position 8 (cm/s)			Sum
	Depth 0.5 m	Depth 1.0 m	Depth 1.5 m	Depth 0.5 m	Depth 1.0 m	Depth 1.5 m	Depth 0.5 m	Depth 1.0 m	Depth 1.5 m	Depth 0.5 m	Depth 1.0 m	Depth 1.5 m	
Simulated water velocity measurements													
3	9.14	6.10	0.00	18.29	18.29	0.00	15.24	12.19	6.10	9.14	6.10	6.10	106.69
6	18.29	6.10	0.00	18.29	15.24	6.10	18.29	6.10	6.10	18.29	12.19	9.14	134.13
9	6.10	6.10	0.00	12.19	9.14	6.10	9.14	6.10	6.10	12.19	12.19	6.10	91.45
12	6.10	0.00	0.00	3.05	9.14	6.10	6.10	3.05	3.05	12.19	12.19	9.14	70.11
15	15.24	12.19	0.00	12.19	6.10	6.10	3.05	24.38	12.19	12.19	9.14	9.14	121.91
18	36.58	27.43	18.29	30.48	12.19	3.05	6.10	9.14	3.05	24.38	18.29	12.19	201.17
												Actual total	725.46
Simulated water velocity measurements for shrimp pond aerator layout A													
3	9.14	6.27	0.00	18.29	18.29	0.00	15.24	12.55	6.10	9.42	6.27	6.27	107.84
6	18.29	6.27	0.00	18.89	15.24	6.27	18.29	6.27	6.10	18.29	12.55	9.42	135.88
9	6.10	6.10	0.00	12.55	9.14	6.27	9.42	6.27	6.27	12.55	12.55	6.27	93.49
12	6.27	0.00	0.00	3.15	9.42	6.27	6.27	3.15	3.15	12.55	12.55	9.42	72.2
15	15.24	12.55	0.00	12.55	6.27	6.27	3.15	24.38	12.55	12.55	9.42	9.42	124.35
18	36.58	27.43	18.29	30.48	12.55	3.15	6.27	9.42	3.15	24.38	18.29	12.55	202.54
												Simulation total	736.30
												Percentage difference	1.47%

Particle study in shrimp pond aerator layouts A, B, C

The particle study feature within the SolidWorks Flow Simulation played an integral role in the study, enabling an exhaustive examination of the mobility and conduct of suspended solid particles within shrimp ponds across the three aerator layouts (A, B and C), as shown in Figs. 3A–3C. This advanced simulation tool furnished valuable insights into the sedimentation patterns and waste management, which are crucial for refining shrimp pond conditions and enhancing the efficiency of shrimp harvesting protocols. By means of the particle study, a meticulous arrangement of 100 particles was established that provided tracers within every aerator layout. This setup aimed to precisely replicate the motion of suspended solids or shrimp within the aquatic environment and to facilitate a more profound comprehension of the aggregation and settling behavior of these particles, thereby yielding crucial insights into the effectiveness of sludge accumulation via the aerators.

Furthermore, the particle study facilitated an intricate comparison of sediment aggregation efficacy among the three layouts (Figs. 3A–3C). A thorough analysis of the simulation outcomes was conducted to ascertain the quantity of particles effectively gathered at the pond's center in each layout. This quantitative evaluation provided a metric for assessing the aerator layouts' effectiveness in overseeing shrimp harvesting. The particle study facilitated delving into the influence of varying aerator arrangements on the sedimentation patterns and the accumulation of shrimp (Figs. 9A–9C).

Results

Water velocity measurement in shrimp pond: Aerator layout A

Water velocity measurements were conducted at varying distances from the aerator in layout A to comprehend the flow patterns and water circulation within the shrimp pond. The velocity measurement results are provided in Table 2.

Verification of simulation model (water velocity) and analysis of variance

During the process of verifying the simulation model for layout A of the shrimp pond aerator, a comparison was made between the actual water velocity measurements and the simulation results for different aerator numbers (Table 4). The purpose of the ANOVA analysis was to determine whether there were any noteworthy disparities in water velocity across the various aerator numbers. The results showed that there was minimal variance in the "Between Groups" (aerator numbers), as evidenced by the low sum of squares and mean square values. The elevated p value of 0.9762 indicated that the F statistic of 0.0678 lacked statistical significance, as indicated in Table 5. Altogether, these findings strongly indicated that there were no significant differences in water velocity among the three aerators.

Particle study of shrimp pond aerators in layouts A, B and C

Positioning the aerators within the Type A pond at a depth of 0.5 meters below the water surface, the water flow pattern was characterized by having the highest water velocity in front of the spiral aerator, reaching a peak velocity of 20.836 cm/s, while the lowest velocity was 0.52 cm/s (Figs. 5A and 8A–8C). At a depth of 1 m, the maximum water velocity was 16.218 cm/s and the minimum velocity was 2.135 cm/s (Figs. 5B and 8A–8C). At 1.5 m, the highest water velocity was 17.056 cm/s, while the lowest was 0.978 cm/s (Figs. 5C and 8A-8C). This investigation utilized the add particle function to introduce 100 particles into the shrimp pond, enabling the study of aggregate inflow behavior. In terms of particle extraction from the center of the shrimp pond, a single particle was extracted, signifying an extraction efficiency of 1% (Fig. 9A). The system took 46 min to attain a state of steady equilibrium.

Table 5 Analysis of variance results

F-statistic = 0.01382						
p Value = 0.90661						
Summary						
Groups	N	Mean	SD	SE		
Actual	60	9.7033	7.0862	0.9148		
Simulation	60	9.8555	7.0954	0.916		
Analysis of variance summary						
Source	Degrees of freedom					
DF	Sum of squares					
SS	Mean square					
MS	F stat	p Value				
Between groups		1	0.6949	0.6949	0.0138	0.9066
Within groups		118	5932.977	50.2795		
Total:		119	5933.6719			

When the aerator was positioned within a Type B pond at 0.5 m below the water surface, the resultant water flow pattern had a maximum water velocity of 20.413 cm/s and a minimum velocity of 0.379 cm/s (Fig. 6A). Similarly, at a depth of 1 m from the water surface, the maximum water velocity was 19.610 cm/s, while the minimum velocity was 0.404 cm/s (Fig. 6B). At 1.5 m, the maximum water velocity was 19.083 cm/s, with the lowest velocity being 0.516 cm/s (Fig. 6C). Using the add particle function to model 100 particles in the shrimp pond to study the behavior of total inflow at the center of the shrimp pond for suction. Of the 100 particles modeled, 88 were released, illustrating an efficiency of 88% (Fig. 9B). The time required for the system to reach a state of steady equilibrium was 72 min.

Placing the aerator within a Type C layout at 0.5 m below the water surface, the maximum water velocity was 21.396 cm/s and the minimum velocity was 0.374 cm/s (Fig. 7A). Similarly, at 1 m below the surface, the maximum velocity was 20.666 cm/s and the minimum was 0.141 cm/s (Fig. 7B), while at 1.5 m below the water surface, the maximum water velocity was 19.210 cm/s and the minimum velocity was 0.655 cm/s (Fig. 7C). The introduction of 100 particles into the shrimp pond, using the add particle function, facilitated the exploration of total inflow behavior at the center of the pond during suction. Out of these particles, 1 particle was released, indicating an issuance efficiency of 91% (Fig. 9C). The system took 68 min to achieve steady equilibrium.

Discussion

Simulation model verification

The verification process for the simulation model for the shrimp pond aerator layout A was effectively completed through a meticulous comparison of water velocity measurements between real-world data and simulation outcomes (Kang et al., 2004). The ANOVA results indicated there were substantial disparities in water velocity among the different variables. The validation of the simulation model precision yielded an impressive accuracy rate of 98.53% (Table 4).

Particle study for shrimp pond aerator layouts A, B and C

The water velocity at depths of 0.5 m, 1 m, and 1.5 m showed no discernible impact on the effectiveness of sludge aggregation. The positioning of surface aerators was the predominant factor influencing shrimp feces collection. Among the three types of aerators, Type A had the lowest efficiency on the water surface, attributed to the prevalence of areas with diminished water velocities. In contrast, the arrangement of the aerators in the Type B layout was more effective due to the swirling motion of the water in the corners of the shrimp pond (Sobachkin et al., 2014). Notably, the aggregation of sludge was less effective when the sediment accumulated through swirling. The placement of aerators on the water surface in the Type C layout led to a rotation angle similar to that of Type B. However, Type C produced higher velocities. Taking the area into account, the average speed for Type C was greater than for the other types across each range of depths. Elevated depth contributed to an impressive 91% efficiency in sludge aggregation (Liu et al., 2017).

Conclusion

The developed simulation model should be relevant for practical applications in Pacific white shrimp ponds, producing an impressive accuracy rate of 98.53% (Table 4) compared to real-world operations. The shrimp pond aerator layout Type C had 91% efficiency in sediment accumulation, the data on sediment collection efficiency can be of great value for benchmarking, particularly when comparing to Pacific white shrimp harvesting machines that use suction pipes at the central drainage point of the pond. As the research continues and more information becomes available, there is a substantial opportunity for further improvement and enhancement of the Pacific white shrimp harvesting process.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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