BIO Web of Conferences **136**, 01004 (2024) https://doi.org/10.1051/bioconf/202413601004
ISFM XIII 2024

An estimation of dissolved oxygen production model by paddle aerator in whiteleg shrimp (*Litopenaeus vannamei*) culture

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Abstract. Dissolved oxygen is an important parameter in *L. vannamei* culture. The aim of this research is to determine of the oxygen levels produced by the paddle aerator in *L. vannamei* ponds. The research method used is a descriptive method by collecting research data using the causal expose-facto design which is analyzed by a dynamic modeling system. The results showed that water quality parameters were relatively stable during the shrimp culture periods. Based on dynamic modeling studies, the effectiveness of using the paddle aerator will decrease in the third week. According to modeling estimates of 1 HP paddle aerators produce dissolved oxygen levels was 0.5-8.0 mg/L. The oxygen solubility level from using the paddle aerator was lowest when the shrimp culture period reached 50 days and the highest solubility was 7.5 mg/L. The oxygen solubility rate in shrimp pond waters is also influenced by the temperature stability and other abiotic factors. Finally, the oxygen production rate in the paddle aerator oscillates dynamically throughout the shrimp culture cycle with estimated oxygen production rates ranging from 0.5-8 mg/L.

1 Introduction

Litopenaeus vannamei cultivation is one of the most widely developed aquaculture activities in coastal areas of Indonesia [1]. Infrastructure and supporting facilities are necessary for an intensive shrimp farming cycle to be sustainable [2] including paddle aerators, plastic sheeting, pumps, aeration filters, pipes, and anchor boards. Intensive shrimp farming activities require a consistent and competitive aquaculture operational system as a form of investment in successful aquaculture [3].

One of the important tools required for intensive shrimp farming activities is the use of a paddle aerator. The function of the paddle aerator in shrimp farming activities is to supply dissolved oxygen and to maintain stable pond water quality conditions [4]. Another function of the paddle aerator is to maintain the biophysical conditions of the

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waters so that they remain consistent so that the physiological conditions of the cultured shrimp remain good [5].

During the blind feeding period of *L. vannamei* cultivation, it was found that the concentration of temperature and salinity parameters had a correlation with the level of oxygen transfer by the paddle aerator [4]. Since the amount of live shrimp biomass increases, a balanced amount of oxygen carrying capacity was essential [6]. The need for oxygen in shrimp farming activities was an important indicator to determine the success rate of aquaculture, thus its presence must be very carefully observed [7]. Oxygen was a vital parameter that affects the growth rate and survival of shrimp during the cultivation period [8]. Most ponds created their main source of oxygen utilizing paddle aerators, which serve as aquaculture engineering tools. Based on the existing literature references, the purpose of this study was to estimate the level of oxygen production from the use of paddle aerators in *L. vannamei* aquaculture activities. It was intended that this research will provide dynamic analytical information about the estimated level of oxygen production.

2 Materials and Methods

This research was conducted at PT Jhonchin Agromina's intensive shrimp farming pond, located in Lebak Regency from February to May 2021 (one cycle of shrimp cultivation). The research was conducted with the causal ex-pose facto design concept or research according to field conditions without any treatment engineering. The data was collected from field measurements of the temperature, pH, dissolved oxygen, salinity, nitrite, organic matter, TAN (Total Ammonia Nitrogen), phosphate, CO_3, HCO_3, alkalinity, and total bacteria levels in the water. Subsequently, Then, a tabulation of data on shrimp weight, number of stocking densities, and amount of feeding was carried out to provide supporting evidence.

Water quality parameters were measured at the PT Jhonchin Agromina Water Quality Laboratory for data analysis, and secondary data was gathered from the cultivation reports logbook. The data was then obtained in accordance with the research indicators and investigated using the dynamic modeling system analysis program Stella ver. 9.02.

3 Results and Discussions

3.1. Water Quality

The water quality parameters of aquaculture ponds during the study period were presented in Table 1. The condition of the water quality parameters during the study period was considered quite good and stable from one pond to another. The stable character of water quality between ponds was due to the level of treatment and the aquaculture management system using the same procedure. The use of the same method of cultivation procedures allowed for a level of homogeneity of cultivation conditions during the rearing cycle [9]. The same feeding and treatment in aquaculture activities had an impact on the cultivar and pond ecosystem conditions which tend to be relatively stable [10].

Water quality was the most important environmental parameter in intensive shrimp farming activities [11]. In intensive shrimp farming activities, water quality parameters had an interrelated relationship between one parameter and another [12]. Shrimp grow well in conditions of good and stable water quality parameters. On the other hand, inadequate water quality parameters would have an impact on the distribution of disease prevalence in aquaculture environments [13].

A suitable standard of shrimp culture management was one that was oriented towards stable water quality conditions and in accordance with the quality standard values. Physiologically, the condition of good water quality parameters would had an impact on the level of feed consumption by better shrimp [14]. Overall, the amount of productivity of the shrimp culture cycle during the cultivation period would be highly influenced by water quality criteria [15].

Table 1. The water quality parameters of aquaculture ponds

Water Quality	Value in each Ponds					
	A1	A2	A3	A4	A5	A6
pH	7.7-8.2 7.9 ±0.28	7.7-8.3 8.0 ±0.34	7.7-8.3 8.0 ±0.29	7.7-8.3 8.0 ±0.29	7.8-8.4 8.1 ±0.33	7.6-8.3 7.9 ±0.28
Salinity (g/L)	28 ±1.95	28 ±2.14	28 ±1.96	28 ±1.83	27 ±1.70	28 ±2.21
DO (mg/L)	4.31-6.20 5.25 ±0.20	4.31-6.30 5.31±0.22	4.31-6.29 5.30±0.23	4.31-6.40 5.35±0.21	4.30-6.29 5.29±0.20	4.28-6.40 5.34±0.18
Temperature (°C)	29.2-30.8 30 ±0.61	29.2-30.7 29.9±0.57	29.3-30.8 30 ±0.64	29.4-31.0 30.2±0.60	29.4-31.2 30.3±0.59	29.1-30.6 29.8±0.60
CO_3 (mg/L)	8 ±0.8	7 ±0.70	4 ±0.65	7 ±10.1	11 ±0.84	6 ±0.72
HCO_3 (mg/L)	101 ±1.25	101 ±0.94	106 ±1.01	99 ±1.46	98 ±1.74	103 ±9.13
$CaCO_3$ (mg/L)	109 ±7.27	108 ±5.14	110 ±5.37	106 ±5.98	109 ±9.64	108 ±5.20
PO_4 (mg/L)	0.38±0.24	0.27±0.21	0.35±0.25	0.25±0.17	0.25±0.23	0.20±0.13
NO_2 (mg/L)	0.054±0.08	0.083±0.08	0.063±0.07	0.053±0.08	0.093±0.04	0.053±0.04
TAN (mg/L)	0.037±0.08	0.025±0.06	0.071±0.07	0.066±0.08	0.039±0.10	0.029±0.08
TOM (mg/L)	87.15±1.32	85.36±1.42	82.42±1.75	84.78±1.73	84.52±1.34	85.19±1.34
Total Bacteria (cells/ml)	1.06E+05 ±8.85	1.29E+05 ±9.39	1.96E+05 ±7.43	2.76E+05 ±3.36	1.46E+05 ±1.83	1.75E+05 ±1.79

3.2. *Causal Model* of *Paddle Aerator Used*

The causal loop model of the level of dissolved oxygen production in the shrimp pond ecosystem was made based on theoretical studies and analysis of condition phenomena in the field. Causal loop analysis was used for visual and descriptive data assessment based on the conceptual design of the model made [16]. In the causal loop model, data transformation was carried out from descriptive images into data analysis [17]. The description of the causal loop model in this study was described in Figure 1.

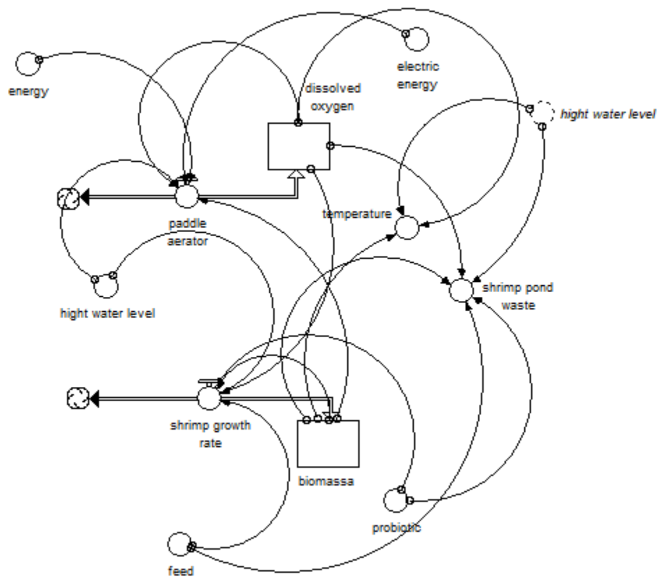

Fig. 1. Causal loop model

Two systems were developed to function in the causal loop model of this research: the first system defined how oxygen may be produced by the paddle aerator, and the second system explained how the biomass of shrimp cultivated in ponds was formed. The amount of electrical power and engine power employed had a significant impact on the paddle aerator's ability to produce oxygen in pond waters [18]. Paddle aerators were specifically used in intensive farming operations to reduce the effects of a drastic drop in dissolved oxygen levels [19].

3.3. Dissolved Oxygen Production Rate

The pond ecosystem produces a certain amount of oxygen through a variety of processes, including photosynthetic activity, the use of paddle aerators, and diffusion. In intensive pond waters, the amount of paddle aerators used has a significant impact on the production of oxygen [20]. Paddle aerators are also used to maintain ponds' levels of stability for water quality measures and the hydrological pattern of the water [21]. Figure 2 illustrated the connection between the efficiency of a paddle aerator and the dynamics of oxygen solubility in intensive pond waters.

In the third week of cultivation, the effectiveness of the usage of paddle aerators would experience a decrease in fluctuations. At almost the same period, the level of oxygen solubility in the pond would also start to decline. These findings almost accurately represent the research of [22], which found that the energy and type of paddle aerators used varied in terms of how successful they were at aerating the water. Figure 2 demonstrated the level of variability in the estimated efficacy of the usage of paddle aerators in these intensive ponds.

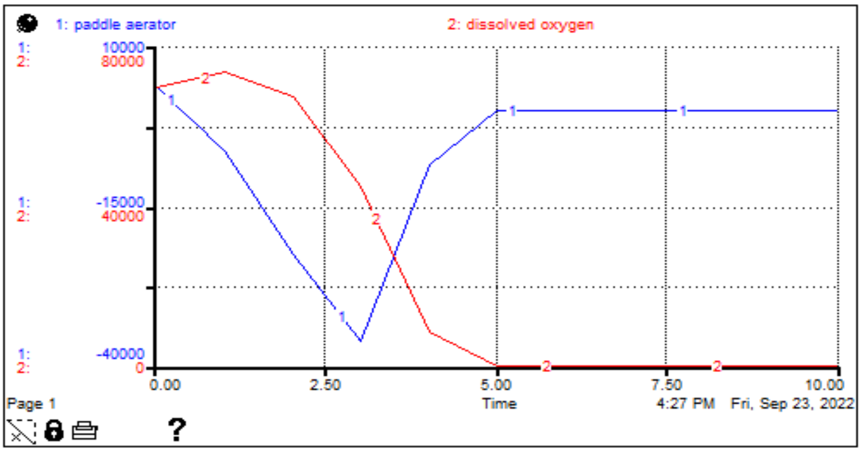

Fig. 2. The level of fluctuation of the estimated effectiveness of the use of paddle aerators

The highest production rate for dissolved oxygen by paddle aerators in ponds was 8 mg/L, and the lowest was 0.5 mg/L (Figure 2). In the second week of culture had the highest oxygen solubility carrying capacity was 9 mg/L. The effectiveness of using a paddle aerator and the amount of oxygen solubility in the pond would be correlated to a similar degree and follow a similar fluctuation rhythm [20].

Throughout the shrimp cultivation, the amount of oxygen solubility in pond waters will also change dynamically [9]. The waters became hypoxic due to the decrease in oxygen solubility, which stressed the shrimp [23]. Shrimp exhibited physiological stress due to reduced oxygen solubility, which resulted in slow growth and high mortality rates [24]. Therefore, managing variable oxygen solubility levels in shrimp ponds required the use of adequate and appropriate paddle aerators.

3.4. Relationship between Oxygen Solubility and Shrimp Production

The presence of sufficient dissolved oxygen concentration was the main requirement for the sustainability of the shrimp culture cycle [25]. The stability of pond water quality, shrimp growth rate, abundance of *Vibrio* sp bacteria and potential levels of reduction and oxidation were also strongly influenced by the presence of sufficient dissolved oxygen concentration [26]. The use of sufficient aeration and regulation of the stocking density of shrimp would greatly affect the dynamics of oxygen solubility in the shrimp culture cycle [3].

The level of oxygen solubility in ponds experienced the lowest fluctuation when the cultivation period enters the age of 50 days and over. The highest level of oxygen solubility was 7.5 mg/L in the early days of cultivation, then decreased as the amount of shrimp biomass increased. The higher the growth rate of shrimp, the level of oxygen consumption for their metabolic needs will also increase [27]. *L. vannamei* were poikilothermic so they were very sensitive to changes in temperature and oxygen solubility in their habitat [28]. The relationship between fluctuations in oxygen solubility and growth rate of shrimp biomass was described in Figure 3.

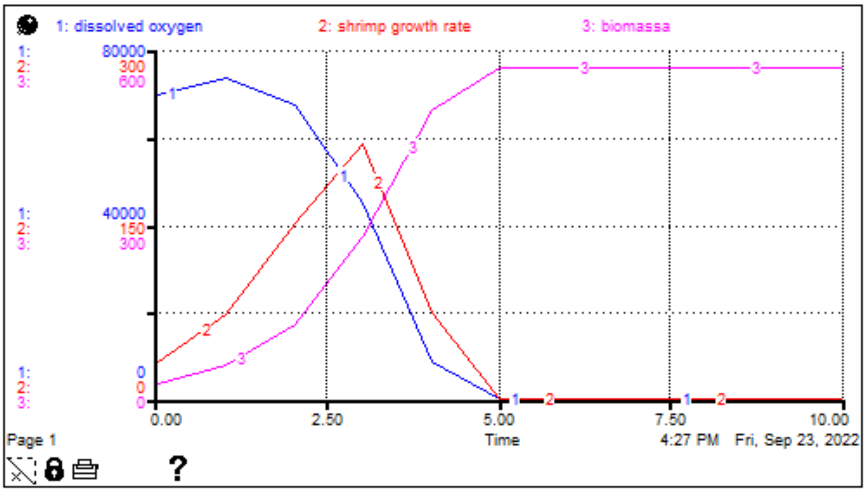

Fig. 3. The relationship between fluctuations in oxygen solubility and growth rate of shrimp biomass

The growth rate of shrimp experienced a decreasing phase at the age of 35 days, this condition was possible due to a decrease in the level of oxygen solubility in the pond. Hypoxic water conditions have a synergistic effect on the declining growth rate of shrimp [28]. The uncontrolled amount of fry stocking density also has an effect on the massive decrease in dissolved oxygen concentration in the waters [29]. The use of a paddle aerator that was in accordance with the carrying capacity of the pond and the placement of the correct position of the paddle aerator would had an impact on the stability of the solubility of oxygen in the pond [18].

3.5. Relationship of Oxygen Solubility with Temperature

The level of oxygen solubility in ponds naturally was strongly influenced by the temperature distribution in the pond water column [28]. The placement and used of the appropriate number of paddle aerators would be greatly affected the level of temperature homogeneity and oxygen solubility in the waters. The interaction between hydrogen micromolecules and the electrostatic effect of the movement of the paddle aerator caused the water column condition homogeneous [30]. This stable water temperature condition had a strong influence on the level of oxygen solubility, shrimp metabolism, diet, growth rate, and post-moulting shrimp performance [31].

Increasing water temperature caused the level of oxygen solubility in the waters decreased [32]. Scientifically, the rate of increase in water temperature had an impact on the decreasing level of oxygen and mineral ion solubility [33]. Increasing levels of water temperature caused the oxidation process increased, so the level of oxygen consumption would be increased [34]. The contradictory relationship between the level of oxygen solubility and the increase in water temperature can be presented in Figure 4.

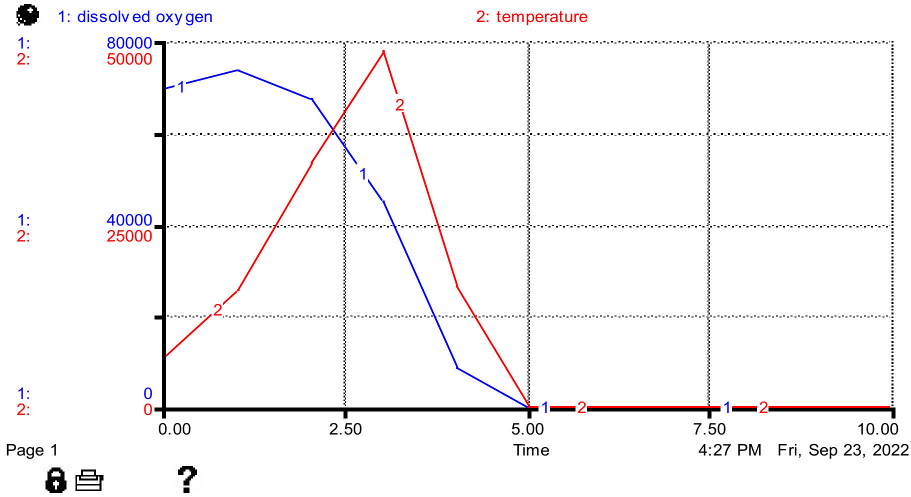

Fig. 4. Relationship between the level of oxygen solubility and the increase in water temperature

One of the functions of using a paddle aerator in pond waters was to maintain the stability of oxygen solubility and temperature stability, the paddle aerator also functions as a tool to collect mud. The current created by the paddle aerator was very useful for carrying pond mud manure to the outlet of the pond [35]. The existence of a paddle aerator was one of them to keep the good cultivation environment [10]. Based on Figure 4, it can be seen that the critical period of decreasing temperature and oxygen solubility level took place at the age of 50 days of cultivation [32].

The shaking of the wheel on the paddle aerator would provide a vertical mix in the water column so that it made the temperature in the waters homogeneous [36]. The higher the paddle aerator swings, the greater the current generated, so that it would be allowed more oxygen diffusion processes to occur [37]. The poikilothermic character of *L. vannamei* and swam in the water column would be very suitable if a paddle aerator was used in the pond in accordance with the carrying capacity of shrimp biomass [38]. The level of carrying capacity of the use of paddle aerators in intensive ponds for every 500 kg of shrimp biomass requires 1 HP paddle aerator [4].

Overall, it can be explained that the stability of water quality in aquaculture was strongly influenced by the used of adequate paddle aerators. Paddle aerators in intensive pond cultivation function as environmental engineering tools including temperature stability and oxygen solubility [3]. In this study, it was explained that the level of oxygen production by the paddle aerator would decrease in the 3rd week of cultivation, this condition resulted in a decrease in the level of oxygen diffusion and growth of the shrimp being reared. Temperature and oxygen were important abiotic factors that affect the rate of metabolism and growth of shrimp in ponds [39]. From this study, it was also found that there was an indication of an increase in water temperature which became heterogeneous due to a decrease in the rate of the paddle aerator, meaning that the use of a paddle aerator also functions as a means of engineering the temperature of pond waters to remain stable. This was in accordance with the opinion of [5], which states that the use of paddle aerators in intensive ponds was one of the functions to minimize the impact of temperature stratification and maintain the circulation of water molecules in the pond so that it remained stable.

4. Conclusion

In this study, the oxygen production rate dynamically by the paddle aerator ran oscillatingly during the shrimp culture cycle with the estimated level of oxygen production ranging from 0.5-8 mg/L. It was known that the dynamic range of oxygen production during one cycle of shrimp culture was known, but the dynamical relationship between the level of oxygen production by the paddle aerator and other water quality parameters had not been clearly described.

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