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Analysis of Growth and Water Quality Dynamics in White Shrimp (*Litopenaeus vannamei*) Cultivation Using the Millennial Shrimp Farming System in Indonesia

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ABSTRACT

Vannamei shrimp (*Litopenaeus vannamei*) is the mainstay of fishery exports in Indonesia. In order to achieve the vannamei shrimp production target, the Millennial Shrimp Farming (MSF) system was developed to make vaname cultivation possible in limited land and relatively small business capital. Although many MSF systems have been carried out, studies reporting on shrimp growth and water quality in MSF systems in Indonesia have not been widely reported. This study aimed to analyze the growth of vaname shrimp and the dynamics of water quality during white shrimp culture with MSF system in Indonesia. The parameters analyzed were daily water quality (pH, DO, Salinity, Brightness), weekly water quality (NH_3, NO_2, PO_4, H_2S), and shrimp growth (survival rate, average body weight, average body length, average daily growth). Water quality measurements were carried out 2 times a day (06.00 am and 04.00 pm). The results in this study indicated that the white shrimp culture system with the MSF system can be used as an alternative to increase white shrimp production in Indonesia. To the best of our knowledge, this study was the first study to report that the white shrimp culture system with the MSF system could be used to maintain water quality in ponds and produced optimal shrimp growth.

Key words : *Vannamei, Shrimp, Aquaculture, Water quality, Microbial ecology*

Introduction

White shrimp (*Litopenaeus vannamei*) was one of the important aquaculture commodities and the mainstay of fishery exports in Indonesia (Hendrajat and Mangmpa, 2017). White shrimp culture has developed rapidly in the last decade, mainly due to the increasing demand in the world shrimp market (Indah *et al.*, 2021). In 2019, Indonesia was targeting a 250% increase in white shrimp exports until 2024. To be able to meet this production target, Indonesia required a massive strategy to increase the productivity of white shrimp aquaculture (Wulandari, 2015).

The efforts to increase the production of white shrimp might be done through intensive cultivation.

The innovation of the white shrimp culture system could be carried out on a smaller scale and start-up capital has been developed in Indonesia. One of these aquaculture innovations was to utilize a circular pond cultivation system. This circular pond cultivation system was designed to be able to attract the interest of young farmers, especially from the millennial generation. With this in mind, the circular pond cultivation system in Indonesia was named Millennial Shrimp Farming (MSF).

As with other aquaculture systems, important parameters that need to be monitored in aquaculture production using the MSF system were water quality and shrimp growth (Asri *et al.,* 2021). Water quality and shrimp growth were closely related, optimum water quality conditions cuold encourage optimal shrimp growth (Kewcharoen *et al.*, 2019). In an effort to increase aquaculture productivity, the effort that was often made by farmers was the addition of stocking density or intensification (Rakhfid *et al.*, 2017). The addition of this stocking density resulted in the addition of feed and the process of excretion resulting in an increase in organic waste in the pond. This increase in waste load caused a decrease in water quality in the pond which in turn would interfere with the growth of cultured shrimp.

Although shrimp farming system with a system MSF began widely grown in Indonesia, studies reporting the dynamics of water quality and shrimp growth in the MSF system was still very rarely reported. In fact, the dynamics of water quality and shrimp growth would be an important evaluation material to continue to develop this aquaculture system in an effort to increase the productivity and export of white shrimp in Indonesia.

This study aimed to analyze the dynamics of the water quality and the growth of farmed white shrimp with MSF system. To the best of our knowledge, this study was the first study to report that the shrimp farming system vaname with MSF system could be used to maintain water quality in ponds and shrimp produce optimal growth.

Materials and Methods

Millennial Shrimp Farming Ponds

This research was conducted in March - May 2021 using 10-meter diameter circular pool with a stocking density of 450 individual s/m^2. Because it is designed to develop vaname aquaculture for millennials, the pond is widely known as the Millennial Shrimp Farming Pond in Indonesia. The shrimp seeds used in this study were F1 seeds obtained from PT. Suri Tani Pemuka, Indonesia.

Water Quality Parameters

The measurement of water quality parameters was divided into daily and weekly water quality parameters. Daily water quality parameters included DO, pH, temperature, brightness, and salinity. Daily water quality parameters were measured by Water Quality Meter Az 86031 (AZ Instrument Corp).

The measurement of other water quality parameters measured regularly in the weekly period. These parameters were the concentration of dissolved ions (NH_3, NO_2, PO_4 and H_2S). NH_3 was measured based on the SNI method. 06-6989-30-2005, PO_4 was measured using the APHA 4500-PO4-2005 method, H_2S was measured by the Automatic Absorption Spectrophotometer, and NO_2 was measured by the JIS method. NO. K0102. 43.2.4.

Growth Parameters

The shrimp population was estimated by subtracting the number of stocked shrimp from the number of dead shrimp. The survival rate (SR) was calculated using the following formula:

$$SR = \frac{Nt}{No} \times 100\%$$

Where SR was survival or SR (%), $N_t$was the number of shrimp at the end of rearing (shrimp), and N_0 was the number of shrimp at the beginning of stocking (shrimp).

Average body weight of shrimp (ABW) was calculated using the following formula:

$$ABW = \frac{Total\ weight}{Total\ population}$$

The total weight was the weight of the shrimp at the time of sampling (gr) and the total population was the number of shrimp populations at the time of sampling. Shrimp average daily growth (ADG) was calculated using the following formula:

$$ADG = \frac{ABWn - ABWt}{T}$$

Where ABWn was the average body weight when sampling was done (gr), ABWt was the previous average body weight (gr), and T was the side time interval (day).

Results

Daily Water Quality Parameters

Dissolved Oxygen (DO) was observed daily (06.00 am. And 6.00 pm) during the cultivation process (Figure 1). The DO measurement results showed the DO value in the afternoon was higher than in the morning. The DO value in the MSF pool showed a decreasing trend along with the addition of Day of Culture (DOC). The highest value of DO in the morning was 5.93 mg/l occurred in the 2nd DOC and the lowest was 3.26 mg/l at the 85th DOC. As for the DO value in the afternoon, the highest and lowest values were 7.91 mg/l (DOC 1) and 3.80 mg/l (DOC 88), respectively.

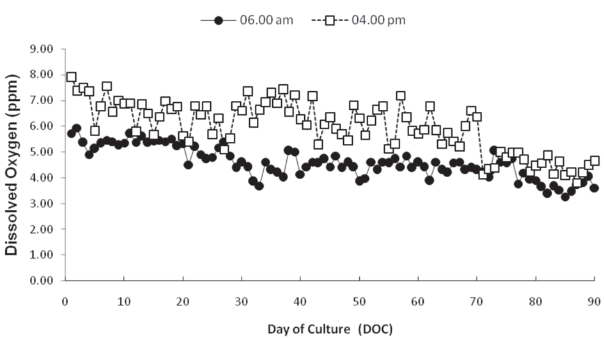

Fig. 1. Dissolved oxygen during cultivation

Similar to DO, pH observations were also carried out every morning (6.00 am) and afternoon (4 pm) during the cultivation period (Figure 2). The pH during the cultivation process fluctuated every day with a decreasing trend along with the addition of DOC. The lowest and highest pH values for the morning were 8.30 and 7.70, respectively. In the observation of pH in the afternoon the highest value was 8.60 while the lowest value was 7.90.

Pond water temperature during the vaname cultivation process was also observed (6.00 am and 4 pm) in this study (Figure 3). In general, the pool water temperature fluctuated daily with values tending to be stable during the study. The highest and lowest temperatures obtained during the study were in the morning, the highest was 29°C and the lowest was 25°C. While the temperature in the afternoon during the observations obtained the highest 31°C and the lowest 27°C.

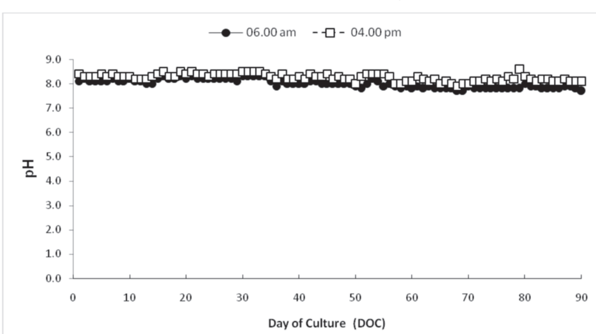

Fig. 2. pH during cultivation

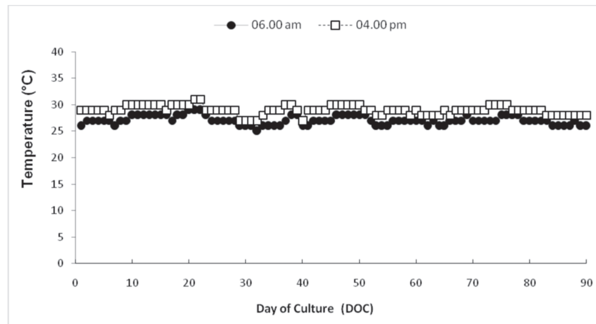

Fig. 3. Temperature during cultivation

The salinity of the pond water during the study was analyzed in this study (Figure 4) at 06.00 am and 04.00 pm daily. In general, the salinity values in the morning and evening did not experience a difference with a tendency to increase every day. The highest and lowest salinity values during the cultivation process were 33 ppm and 27 ppm, respectively.

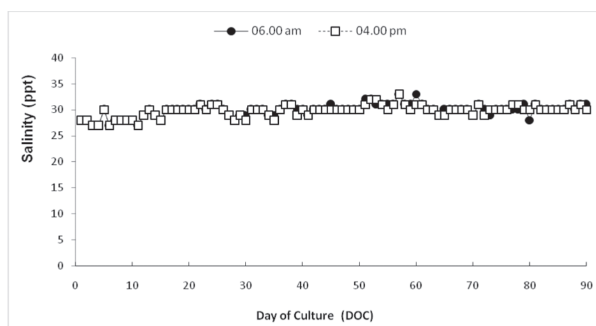

Fig. 4. Salinity during cultivation

Another daily parameter measured in this study was water brightness. Water brightness values were also measured twice a day (06.00 am and 04.00 pm) (Figure 5). From the measurement results during the study, it was known that the brightness of the water in the pond decreased along with the addition of DOC. In general, the water brightness in the morning and evening did not differ with the highest and

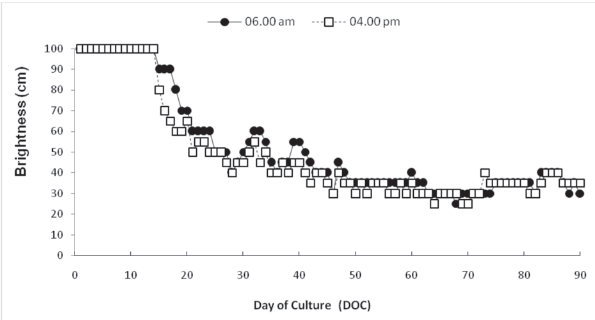

Fig. 5. Brightness during cultivation

lowest values being 100 cm and 25 cm, respectively.

WeeklyWater Quality Parameters

The air quality parameters observed in this study were NH_3, PO_4, H_2S, and NO_2 (Figure 6). All parameters measured in this study showed an increasing trend with the addition of DOC. NH_3 increased from 0.08 ppm at the beginning of cultivation to 0.38 ppm on day 86. NO_2 increased from 0.01 ppm to 0.01 ppm. H_2S increased from 0.01 ppm to 0.25 ppm.

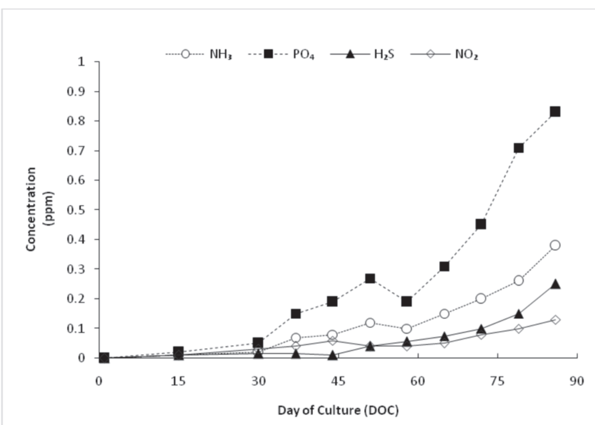

Fig. 6. Concentration of various ions during cultivation

The PO_4 measurement in the study indicated that the PO_4 content tended to increase during the cultivation process. The PO4 value increased from 0.02 ppm at the beginning of cultivation to 0.83 ppm at day 86. The PO_4 value at days 52 and 58 decreased (0.27 ppm and 0.19 ppm, respectively).

Growth Parameters

The total population of shrimp and the value of Survival Rate (SR) of shrimp were analyzed in this study. In addition, vaname growth during the cultivation process was also analyzed by measuring Average Body Weight (ABW), Average Body Length (ABL) and Average Daily Growth (ADG) (Figure 7).

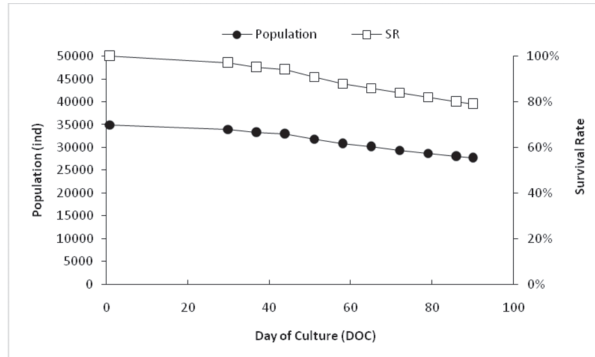

Fig. 7. ABW, ADG and ABL values

The population of white shrimp during the study after the 30th day decreased every week (700 heads/week) so that at the end of the cultivation phase there were 27,650 shrimps left. This was in line with the decrease in the SR value. The results of the SR calculation showed that the value of this parameter decreased 2% constantly after day 30. The SR value at the end of cultivation in this study was 79% (Figure 8).

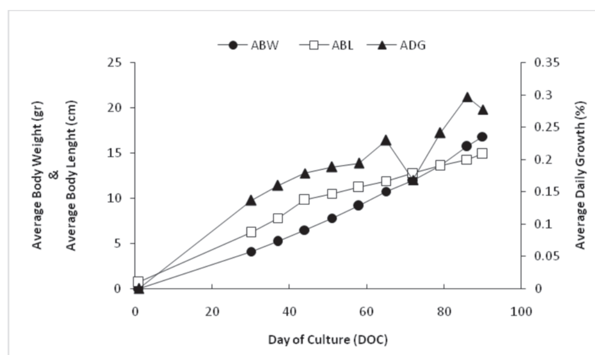

Fig. 8. Popullation and SR values

Average Body Length (ABL) of white shrimp at stocking was 0.7 cm, at the 30th DOC the average length was 6.2 cm. At the 44th DOC it reached 9.8 cm. After that, the growth of vaname length was still ongoing but slower. At 72nd DOC, the average length of shrimp was 12.8 cm, then increased to 14.9 cm at the end of the culture phase.

Avarage Body Weight (ABW) in early stocking 0.01 g and at day 30 reached 4:11 gr with an average growth per day (ADG) reached 0.1%. After the 30th DOC, the average weight of shrimp increased constant between 0.15% - 0.20%. In the DOC 65, an increase in ADG valued 0.23% by average weight of shrimp (ABW) reached 10.7 g. The decrease in ADG occurred in DOC 72 by 0.17% with an ABW of 1.95 gr.

Discussion

The fluctuations in DO value during the study were still in the optimum range for cultivation, including on day 72 which showed a drastic decrease. The concentration of dissolved oxygen (DO) was ideal for the growth of the shrimp is 4.5 to 7 mg /l (Rao *et al.,* 2017). Decreasing DO would result in greater opportunities for shrimp farming failure (Li *et al.,* 2020). The DO measurement in the morning showed a lower value than the DO measurement in the afternoon. During the day there was a supply of oxygen through photosynthesis by phytoplankton, so that when measured in the afternoon, the DO value would be higher than in the morning. DO fluctuations and water temperature really need to be understood as a capital for the management of aquaculture pond water quality (Ariadi *et al.,* 2021).

DO measurement in this study indicated that the DO value decreased along with the addition of DOC. The decrease was due to the increased load of organic material during the production process. Oxygen in the culture media was not only used for white shrimp respiration, but it was also needed for the decomposition of organic matter. The increase in ammonia content with increasing maintenance time caused a decrease in DO content in the waters (Widigdo and Yusli, 2013; Suhendar *et al.,* 2020).

The pH value during the study was still in a good range for white shrimp culture. The optimal range of pH values for white shrimp culture ranges from 7.0-8.5 (Effendi *et al.,* 2019). In this range, shrimp could experience optimal growth. The pH concentration of the water affected the shrimp's appetite and chemical reactions in the water. In addition, a pH that was below the tolerance range caused moulting difficulties where the skin becomes soft and the survival rate was low.

The pH value showed a decreasing trend during the cultivation phase, although there was a significant increase before the 30th DOC. The pH value of the water was influenced by the concentration of CO_2. Photosynthesis caused the concentration of CO_2 to decrease, so the pH of the water would increase. On the other hand, at night all organisms in the water released CO_2 so that the pH of the water decreased. This decreased in pond water pH could occur due to the decomposition or decomposition of organic matter by microorganisms (Supriatna *et al.,* 2020).

Temperature fluctuations during the cultivation period were still in the optimum value for white shrimp culture. The optimal temperature for the growth of vannamei shrimp was 27-34°C (Supriatna *et al.,* 2020). If the temperature was more than the optimum, then the value in the shrimp body metabolism was rapid. However, if the temperature was lower than the optimum temperature, then the shrimp appetite might decrease resulting in a decrease in the growth of shrimp.

Although the brightness level during the cultivation process in this study decreased, the brightness value was still in the optimum range (Dewi *et al.,* 2019). This decrease in brightness could be caused by an increase in the amount of suspension in a body of water. DOC had an effect on the TSS content which tends to be higher as the age of cultivation increases (Widigdo and Yusli, 2013). The cause was the accumulation of leftover feed, shrimp manure, and phytoplankton along with the increase in DOC.

The lowest and highest salinities in the cultivation phase in this study were 27 and 33, respectively. Good salinity for growth ranges from 10-35 ppt (Purnamasari *et al.,* 2017), so the salinity value in the MSF system in this study was within the ideal range. In general, the salinity in MSF ponds had increased slightly. This increase could occur due to the process of evaporation of pool water. The higher the evaporation rate, the higher the salinity value (Rifki *et al.,* 2018). The salinity value which tended to be stable in this study could occur because the evaporation rate was not drastic. This evaporation rate was possible because each MSF pond used in this study was covered by paranet. Giving a cover or roof to an indoor or semi-indoor pool would inhibit the rate of evaporation, thereby holding back the rate of increase in salinity (Maica *et al.,* 2014). The low evaporation rate was also an advantage because a drastic reduction of water flow could be avoided.

The NH3 content in this study until the 65th day was still below 1.5 mg/l. This meant that the NH_3 level was still in the optimum level of cultivation. However, at the 72nd DOC the NH_3 value has reached 0.2, which meant it was above the optimum value. The optimal NH_3 content for the growth of white shrimp was 0.01-0.2 ppm (Ghufron *et al.,* 2017). However, if other water quality parameters were in the optimum range, it was possible that the shrimp could still grow well.

The optimum standard of phosphate levels in the waters was 0.05 – 0.25 mg/l (Awanis *et al*. (2017). Phosphate levels in the MSF system in this study showed the optimum value up to the 30th DOC. After this time, phosphate levels fluctuated and generally increased.The increase in organic matter load along with the increase in DOC caused the phosphate content to fluctuate and increase (Ge, 2016).

The optimum concentration of H_2S was <0.03 mg/l (Triani, 2005). H_2S content exceeding 0.1 mg/ l could inhibit growth and caused disease in shrimp. In this study, the concentration of H_2S on the first day until the 44thday of cultivation was still below the toxicity threshold, but at the 51st DOC it was already at the threshold. After the 72nd DOC, the H_2S content had reached above 0.1 mg/l. These results indicate that in vaname cultivation with the MSF system, the H_2S content should be more careful after the 51st DOC. However, the value of shrimp growth in this study indicated that the increase in H_2S concentration that occured in the MSF system could still be tolerated by the cultured white shrimp.

The value of NO_2 in this study was still in the optimum value. However, on the 79th day it had exceeded 0.1 ppm where above that value the environmental conditions were not ideal for the growth of vaname shrimp. The optimal NO_2 for white shrimp growth was around 0.01-0.1 ppm (Ghufron *et al*., 2017).

Some metabolic products, especially H_2S, NO_2, NH_3 could be harmful to shrimp. NO_2 in aquaculture ponds came from NH_3 which was converted to nitrite by bacteria or mineralized feed and feces residues to form NH_3 which was converted to NO_2 (Sugiyo *et al.*, 2010; Ekawati *et al*., 2021).

The accumulation of organic and inorganic waste as well as toxic compounds such as fish metabolism products in the form of NH_3 could occur at the bottom of the pond. The pond bottom tended to be anaerobic which could trigger the emergence of hazardous compounds such as H_2S (Pantjara *et al.*, 2010). Management of pond bottom with MSF system was needed to minimize accumulation of organic matter on pond bottom.

While the high value of phosphate in the study was due to the high input of organic matter input following the age of shrimp culture. The low frequency of water changes (max. 10% per day) carried out in the MSF system could also trigger high levels of NH_3 and could lead to an increase in phosphate concentrations in the pond.

Most of the water quality parameters either daily or weekly in this study were within the optimum range vaname shrimp growth. These results indicated that the cultivation system with the MSF system was able to maintain water quality during the white shrimp culture process. Increased organic matter load as a consequence of the increase in the number of feed and excretion results as the growth of the shrimp seemed to be accommodated by the MSF system so that the quality and stability of aquatic systems in aquaculture ponds could be maintained to support the growth of shrimp. When water quality could be maintained, the growth of vaname was expected to continue well. The growth parameters of vannamei shrimp (SR, ABW, ABL, ADG) were also analyzed in this study with the aim of knowing whether the MSF system cultivation could successfully support the growth of cultured shrimp.

Survival Rate was one of the parameters to determine the survival rate of an organism (Ariadi et al., 2020). SR at the end of cultivation with the MSF system in this study reached 79%. This result was included in the good category even though the cultivation target was mostly harvested with an SR of 80%. With an SR of 79% at DOC 90, the total population of shrimp in the pond in this study was 27,650 individuals. SR with a value above 85% was classified as very good and in the range of 75% - 80% was in the good category (Khoa *et al.,* 2020).

Averge Body Weight at the end of the cultivation phase in this study reached 16.83 g/ind at the age of 90 days. This weight was included in the category of good yields where for intensive white shrimp production the average ideal weight of shrimp at the age of 81 – 120 days was 12.1 g – 20.00 g (SNI No. 01-7246, 2006). The results of ADG measurements in the study increased, especially at DOC 79 (0.24 g/ head per day), DOC 86 (0.30 g/head per day) and at harvest DOC 90 (0.28 g/head per day). The ideal ADG value was 0.2 g/head per day (SNI No. 01-7246). These results indicated that the application of white shrimp culture with the MSF system could meet the ideal aquaculture target.

The results of the analysis of white shrimp growth parameters carried out in this study showed that vaname cultivation with the MSF system could support shrimp growth well. This was inseparable from the condition of water quality in the MSF system pond which could be maintained properly. Good shrimp growth indicated that the MSF system could be used as an alternative technology for white shrimp cultivation in Indonesia.

Conclusion

The growth and dynamics of water quality in vaname cultivation with MSF system were analyzed in this study. The results showed that in general the water quality in ponds with the MSF system could be maintained to be in the optimum range for the growth of white shrimp. Water quality conditions could be maintained optimally up to DOC to 70, then increased sharply until the end of the study. Although the water quality conditions showed a significant decrease after the 70th DOC, the life and growth of the shrimp could be maintained in a good range. The results in this study indicated that the white white shrimp culture system with the MSF system could be used as an alternative to increase the production of white shrimp in Indonesia.

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