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Original Research Paper

Variation in Water Quality at Different Intensive Whiteleg Shrimp, *Litopenaeus vannamei*, Farms in East Java, Indonesia

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ABSTRACT

Measurement of nine water quality parameters were performed every two weeks in two shrimp farms for one production cycle, located in Tuban and Probolinggo, East Java Province, Indonesia. The average productivity for Farm 1 was 17,142.86 kg/ha, with an average size of 17.88 g; while the productivity for Farm 2 was 18,333.33 kg/ha, with an average size of 14.36 g. During the shrimp cultivating period, mean values for salinity, pH and dissolved oxygen (DO) in both the farms were significantly different, whereas temperature in both the farms was not different. TAN, nitrite and orthophosphate concentrations in both the farms were not different. But for nitrate and TSS, the levels are higher in Farm 2 than in Farm 1. The authors conclude that, compared with Farm 1 (water exchange and earthen pond), Farm 2 (zero-water exchange and lined pond) had significantly higher survival rate and higher environmental profits.

INTRODUCTION

Shrimp farming industry in Indonesia was started in East Java in late 1980s (Taw 2005), and it has become a significant aquaculture activity up to now (Fakhri et al. 2013). In 2002, specific pathogen free *Litopenaeus vannamei* were introduced and have been cultured in most regions in Indonesia, especially in East Java. In 2014, Indonesian government went to improve shrimp production as much as 6,99,000 tons through intensification program (Ministry of Marine Affairs and Fisheries 2010). Intensive shrimp culture is characterized by high quantity and quality of feed input and high stocking density in pond (Piedrahita 2003). One of the main problems with intensive shrimp pond is the accumulation of toxic inorganic nitrogen in the form of NH_4^+ and NO_2^- (Colt & Armstrong 1981).

In intensive aquaculture system, nitrogen has strongly caused the dynamics of aquaculture systems as a nutrient and toxicant (Burford & Lorenzen 2004). The main source of nitrogen originates from artificial feed that contains protein content in the range of 13-60% (2-10% N) (Stickney 2005). However, the nitrogen from feed can be assimilated into shrimp biomass is only about 25% (Avnimelech 1999). Moreover, shrimp feed contains 1% of phosphorus and approximately 23% of the phosphorus can be converted into biomass (Davis & Arnold 1998).

In shrimp culture, the maintenance of good water quality is highly important to achieve an optimum shrimp production (Lazur 2007). The water exchange is the common method to reduce the accumulation of ammonia and organic matter (Boyd 2003) and to prevent deterioration in pond water quality (Burford et al. 2003). However, aquaculture wastes may contain a variety of constituents including dissolved or particulate organics, nutrients and specific organic or inorganic compounds that could cause poor impact when discharged into the environment (Piedrahita 2003). Moreover, the new water that was introduced into the ponds will cause high mortality due to the change in water quality suddenly (Kongkeo 1997). Therefore, reducing water exchange is an adaptive solution to minimize the possibility of disease transmission in shrimp ponds (Hargreaves 2013). In Indonesia, a minimum or zero water exchange strategy in shrimp culture has been implemented since 2001 (Taw 2005). The present study aims to compare the water quality and shrimp production at two intensive *L. vannamei* farms. The present study proposes a quantitative description of water quality characteristics at two shrimp farms in East Java Province, Indonesia, for one cultivating cycle of shrimp production. Farm 1 is characterized by water exchange strategy and earthen ponds, while Farm 2 is identified with zero-water exchanges strategy and lined ponds. This information was used to: (a) summarize values of 9 water quality variables from two shrimp farms; and (b) evaluate the influence of every two week variations in water quality dynamics in these shrimp farms.

MATERIALS AND METHODS

Shrimp farm management: The study was conducted at two intensive shrimp farms in Tuban and Probolinggo, East Java Province, Indonesia. Farm 1 is located in Tuban. Shrimp culture was started from March to June 2013; 2 shrimp ponds (P1 and P2) were chosen for the study. All the ponds were earthen ponds and aerated with paddle wheels and propellers (70 hp/ha). The pond was about 0.35 ha in area and 1.3 m in depth. Ponds were maintained with water exchange strategy. Water exchange rate was 10% of the pond volume per day, seven days per week. First, water was discharged and then added to refill ponds. No water exchange occurred during the first month of the culture.

On the other hand, Farm 2 is located in Probolinggo. From June to September 2013, 2 shrimp ponds (G5 and G6) were chosen for the study. All the ponds were fully lined with high-density polyethylene (HDPE) liners and aerated with paddle wheels and propellers (60 hp/ha). The pond was about 0.09 ha and 1.5 m in depth. Ponds were maintained without water exchange throughout the growing season. Accumulation of organic matter in the centre of pond was removed regularly via central drains or siphons.

Postlarvae (PL10) *L. vannamei* for pond stocking were obtained from the same hatchery. All the ponds were stocked with high health and specific pathogen free white shrimp on March 20 and June 21 at a typical density of 160 and 150 individuals/m^2 in Farm 1 and Farm 2, respectively.

A commercial pellet was supplied during the production cycle in both intensive shrimp farms. The composition of the commercial pellet was dry matter 88%, crude protein 30-32%, crude fibre 4% and crude fat 5%.

Lime and iron were added in both farms during the production cycle to buffer the pH and bind the sulphides released from the sludge. Moreover, molasses was added to gain bacterial growth.

Sampling and analytical methods: Farm 1 and Farm 2 were sampled for water quality parameters every two weeks from 20/4/13 to 23/6/13 and 28/7/13 to 8/9/13, respectively. Sampling time was between 12.00 and 14.00 h in both farms. Temperature, pH, salinity and dissolved oxygen were measured *in situ* during the sampling process. At each pond, duplicate water samples were collected 30 cm below the water surface (Biao et al. 2009). Samples were placed in a cool, dark place and immediately transported to the on-site field laboratory for analysing total ammonia nitrogen (TAN), nitrate, nitrite, orthophosphate and total suspended solids (TSS).

A variety of water quality parameters were monitored (Table 1). The water quality parameters consist of temperature, pH, dissolved oxygen, salinity, nutrients (TAN, nitrite, nitrate and orthophosphate), and TSS.

Statistical analysis: Statistical analysis was performed using SPSS 16.0. Data were analysed using independent *t*-test to examine the existence of significant difference in water quality and shrimp production between two shrimp farms. Levels of significance were expressed as $P < 0.05$.

RESULTS

Shrimp was harvested on 24 June and 29 September 2013 in Farm 1 and Farm 2, respectively. The overall average of shrimp production is reviewed in Table 2. The average harvest size in Farm 1 and Farm 2 was 17.88 g and 14.36 g, respectively. Production was 17,142.86 kg/ha and 18,333.33 kg/ha for Farm 1 and Farm 2, respectively. Feed conversion ratio (FCR) for Farm 1 and Farm 2 was 1.38 and 1.32, respectively. There was no significant difference in harvest size, productivity and FCR between both farms.

Survival rate (SR) in Farm 1 was 60%, which is significantly lower than in Farm 2 with survival rate of 84.99%. But for specific growth rate (SGR), the value is higher in Farm 1 than in Farm 2. There was a significant difference in SR and SGR between two farms.

Table 3 gives the overall means of physico-chemical parameters of the water quality in two farms. Variations for each water quality parameter is displayed in Figs. 1 to 9.

The variation of temperature values in both farms is given in Fig. 1. The overall average water temperature was 29.96°C and 29.52°C in Farm 1 and Farm 2, respectively. There was no significant difference in temperature values between two farms during the growing phase.

pH values in Farm 1 varied from 6.84 to 8.32, significantly lower than that in Farm 2 throughout the growth season (Fig. 2). There was a significant difference in pH between two farms.

Dissolved oxygen concentrations varied from 7.5 to 9.6 mg/L and 6.6 to 8.5 in Farm 1 and Farm 2, respectively (Fig. 3). There was a significant difference in dissolved oxygen concentrations between two farms during production cycle.

Salinity in Farm 1 ranged from 10 to 12‰ and showed to be significantly lower than in Farm 2, where salinity varied from 19 to 21‰ (Fig. 4). There was a significant difference in salinity between two farms during the growing cycle.

The path of TAN concentrations monitored was different between Farm 1 and Farm 2 during growing cycle (Fig. 5). The TAN concentrations in Farm 1 was a little higher than those observed in Farm 2. The TAN concentrations in Farm 1 and Farm 2 were 0.082-0.437 mg/L and 0.027-0.178 mg/L. In both farms, the TAN concentrations increased dur-

Table 1: Variables studied and corresponding methodology.

Variable	Method
pH	pH meter
Dissolved Oxygen	DO meter
Temperature	Thermometer
Salinity	Refractometer
TAN	Spectrophotometry
Nitrate	Spectrophotometry
Nitrite	Spectrophotometry
Orthophosphate	Spectrophotometry
TSS	Gravimetric

Table 2: Means (± SD) of *L. vannamei* production in two farms.

Variable	Farm 1	Farm 2
Total harvest (kg)	6,000.00 ± 162.63	1,650.00 ± 212.13
Harvest size (g)	17.88 ± 0.89	14.36 ± 1.44
Productivity (kg/ha)	17,142.86 ± 464.67	18,333.33 ± 2,357.02
SGR (%)	10.19 ± 0.04	9.34 ± 0.42
SR (%)	60.00 ± 2.83	84.99 ± 2.35
FCR	1.378 ± 0.01	1.32 ± 0.01

Table 3: Means (± SD) of physico-chemical parameters in two shrimp farms.

Parameter	Farm 1	Farm 2
Temperature (°C)	29.960 ± 0.600	29.520 ± 0.250
pH	7.290 ± 0.510	8.600 ± 0.160
DO (mg/L)	8.810 ± 1.170	7.170 ± 0.640
Salinity (‰)	10.830 ± 0.830	19.500 ± 1.310
TAN (mg/L)	0.224 ± 0.191	0.137 ± 0.166
Nitrate (mg/L)	3.842 ± 1.286	8.652 ± 3.175
Nitrite (mg/L)	0.666 ± 0.243	1.531 ± 0.730
Orthophosphate (mg/L)	0.132 ± 0.082	0.370 ± 0.308
TSS (mg/L)	411.00 ± 69.60	1413.60 ± 338.686

ing the growing phase. There was no significant difference in TAN concentrations between two farms.

There was a significant difference in nitrate concentrations between two farms. The nitrate concentrations in Farm 2 was significantly higher than in Farm 1 during the production cycle (Fig. 6). The overall average nitrate concentrations were 3.842 and 8.652 in Farm 1 and in Farm 2, respectively. The variation of nitrite and orthophosphate concentrations is described in Fig. 7 and 8, respectively. Fluctuation trend of nitrite and orthophosphate concentrations was found in Farm 2, while the nitrite and orthophosphate concentrations in Farm 1 were more stable throughout production. There was no significant difference in these two nutrients between two farms.

TSS concentrations in both farms increased throughout the cultivating period (Fig. 9). The TSS concentrations in Farm 1 varied from 308-459 mg/L, while the TSS concentration in Farm 2 ranged from 1,076-1,876 mg/L. The TSS concentrations in Farm 2 were significantly higher than those in Farm 1. There was a significant difference in TSS between two farms.

DISCUSSION

Environmental and management factors may affect pond water quality and shrimp production (Funge-Smith 1996). Moreover, different management systems between farms may affect survival rate and growth of *L. vannamei* (Biao et al. 2009). In Farm 1, all ponds were the earthen ponds and utilized water exchange strategy. On the contrary, all ponds in Farm 2 were lined ponds and applied zero-water exchange strategy. The variations of water quality were observed in both farms but all values of the parameters are in the desirable range for shrimp culture. The results of the water quality in both farms are discussed below.

Temperature: Water temperature in both farms was ideal for survival and growth of *L. vannamei* in tropical area. According to Hariati et al. (1996), the water temperature value between 26-30°C is optimal to shrimp culture during cultivating period.

pH: Water pH in Farm 2 is more alkaline than in Farm 1. The lower pH values in the Farm 1 is likely because of deficiency of lime administration in this system. Water pH in shrimp culture is influenced by respiration, photosynthesis (Wurts & Durborow 1992), pond soil and addition of limestone (Lazur 2007).

Salinity: Application of salinity concentration in both farms was different. Farm 1 applied low salinity concentration with an average concentration of 10.83‰, while Farm 2 applied high salinity concentration with an average concentration of 19.50‰. Salinity variation at each pond is mainly caused by the evaporation rate and the rainfall during the production cycle (Biao et al. 2009). In this study, different salinity concentrations in both farms were not related to shrimp productivity, but they may affect survival rate and growth of shrimp.

Dissolved oxygen: Dissolved oxygen (DO) concentrations are higher in Farm 1 than in Farm 2. The higher oxygen concentrations in Farm 1 are apparently because of the higher number of aerators used in the pond. Nevertheless, the DO levels in both farms meet the requirements for shrimp production (Boyd 2010).

Nutrients (TAN, nitrite, nitrate and orthophosphate): TAN concentrations in farms increased during the cultivating period. Biao et al. (2009) explained that the accumulation of ammonium in pond is caused by increasing of feeding rates throughout the production cycle. TAN is the ni-

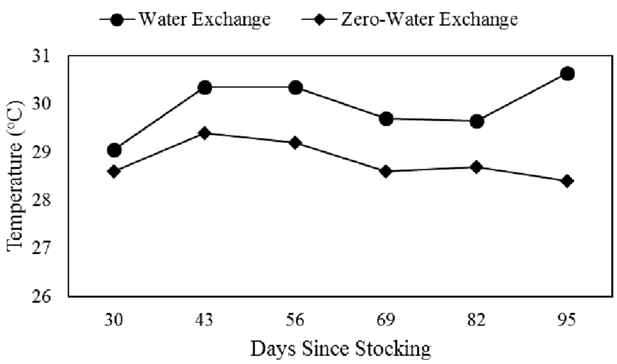

Fig. 1: Variation of temperature in Farm 1 and Farm 2.

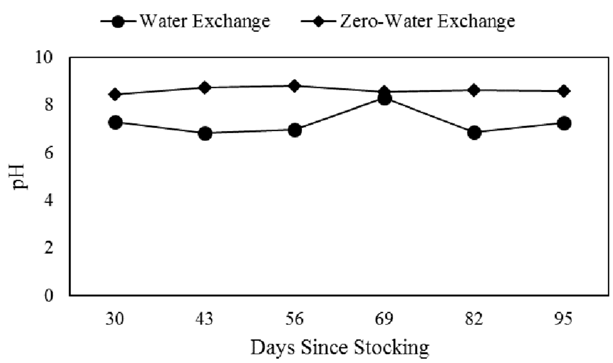

Fig. 2: Variation of pH in Farm 1 and Farm 2.

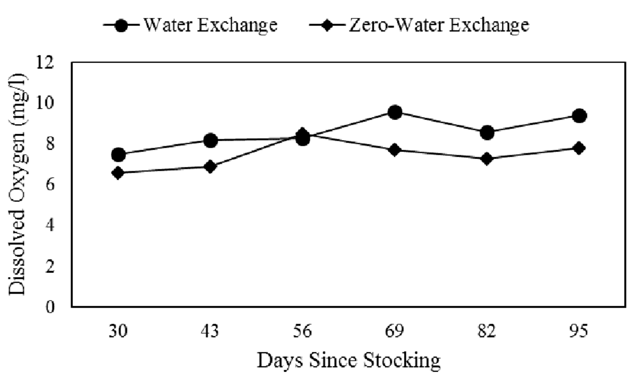

Fig. 3: Variation of dissolved oxygen in Farm 1 and Farm 2.

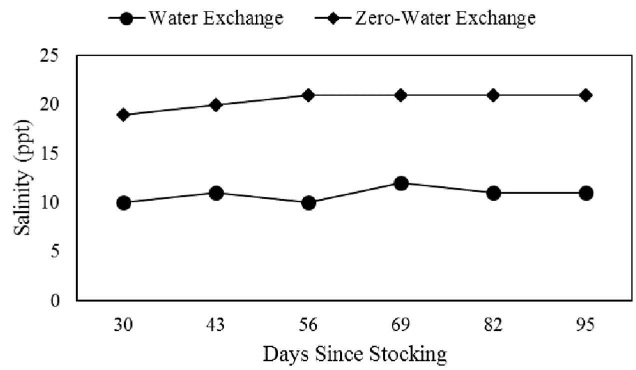

Fig. 4: Variation of salinity in Farm 1 and Farm 2.

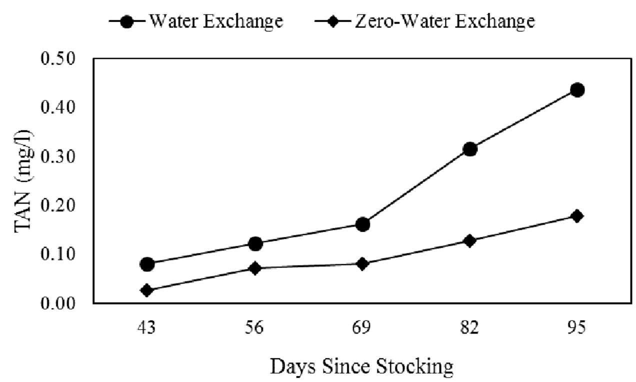

Fig. 5: Variation of TAN in Farm 1 and Farm 2.

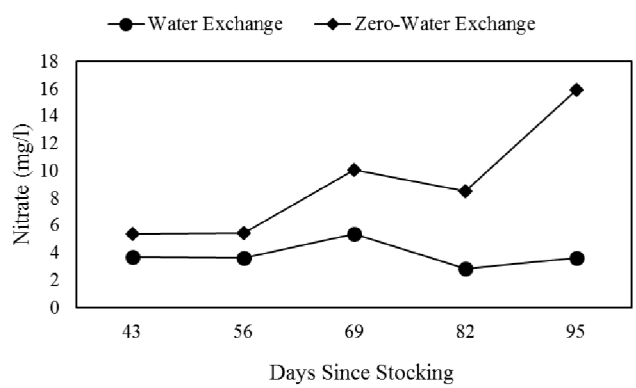

Fig. 6: Variation of nitrate in Farm 1 and Farm 2.

trogenous product from crustacean excretion or remineralization of lost feed (Burford & Lorenzen 2004). The TAN concentrations in Farm 2 with zero-water exchange strategy were slightly lower than in Farm 1 with water exchange strategy. This result is supported by Lorenzen et al. (1997), who reported that ammonia concentrations were lowest at no water exchange pond compared with water exchange pond. However, water exchanges of less than 20% per day with stocking densities (>100 animals per m^2), would maintain TAN concentrations < 4mg/L and should not endanger shrimp growth (Allan et al. 1990).

In this study, there was no significant difference in nitrite and orthophosphate concentrations between two farms. This result is supported by Funge-Smith (1996), who reported that the nitrite and orthophosphate concentrations were not different between lined and earthen ponds. However, the nitrite concentrations in Farm 1 were slightly lower than in Farm 2. Jackson et al. (2003), showed that the nitrite

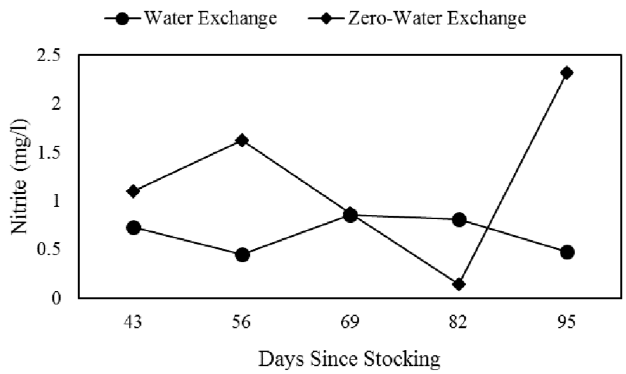

Fig. 7: Variation of nitrite in Farm 1 and Farm 2.

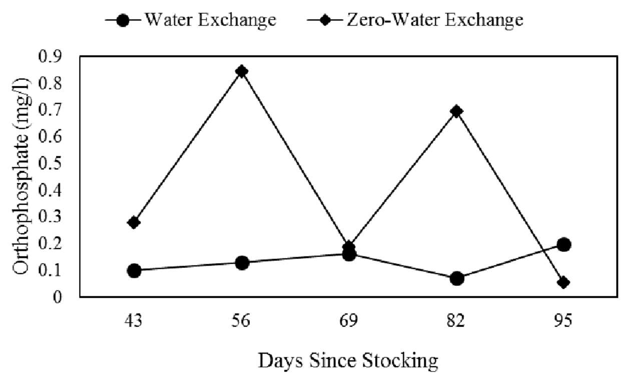

Fig. 8: Variation of orthophosphate in Farm 1 and Farm 2.

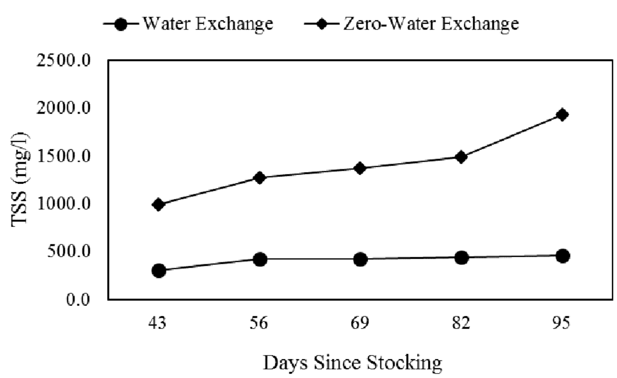

Fig. 9: Variation of TSS in Farm 1 and Farm 2.

concentrations in water exchange pond were low during the production season.

The nitrate concentrations in Farm 1 were significantly lower than in Farm 2. Bratyold & Browdy (1998) hypothesized that the water exchange strategy caused a slow growth of nitrifying bacteria compared with zero-water exchange strategy where nitrification rates were significant. Moreover, Briggs & Funge-Smith (1994) explained that the nitrate concentrations in intensive earthen ponds with water exchange generally remain low throughout the cultivating period.

In general, the TAN, nitrite and nitrate values in both farms were too low to have a negative impact on shrimp growth (Hariati et al. 1996).

TSS: The TSS concentrations in both farms increased over the cultivating season. This may be attributed to the high biomass and high commercial pellet input in the shrimp pond (Biao et al. 2009). Moreover, Martin et al. (1998) explained that increase of suspended solids over time was related to the production of shrimp. The TSS concentrations revealed significant difference between two farms. The zero-water exchange had significantly more suspended solids than the water exchange, which were the same as reported by Samocha et al. (2010). Shrimp is one of the species that can tolerate high solids concentration in water (Hargreaves 2013).

CONCLUSION

During the shrimp cultivating period, mean values for pH, salinity and DO in both farms were significantly different, while there was no difference in temperature between the two farms. The TAN concentration in Farm 1 was slightly higher than in Farm 2. For nitrite and orthophosphate, mean levels in Farm 2 were found to be slightly higher than in Farm 1. The higher nitrate and TSS concentrations were found in Farm 2. The TAN and TSS levels increased during the cultivating season in both the farms.

The variation of water quality variables monitored in ponds was strongly influenced particularly by pond management practices. Our results showed that water quality (nitrate and TSS) is significantly higher in farm management with zero-water exchange and lined ponds. But for TAN, nitrite and orthophosphate levels in both the farms were equivalent. In this study, the water quality in both farms meet the requirement for shrimp culture.

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