Effect of Different Stocking Density to the Growth Performance of Pacific White Shrimp *Litopenaeus vannamei* Cultured in Concrete Tank Using Air Fine Disc Diffuser

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Abstract

Key words: *Density, Growth performance, Concrete tank, Litopenaeus vannamei*

1. Introduction

Recently, most of the shrimp farms, especially in Indonesia, has shifted from extensive or semi-intensive ponds to the intensive and even supra-intensive technology system with high stocking density ranging from 110 – 500 shrimp/m^2 or intensive and >500 shrimp/m^2 for supra-intensive farming system (Zulkarnain et al., 2020). There are advantages and disadvantages of using (supra) intensive technology. According to Samocha (2019), high stocking density of shrimp in intensive system will lead to greater yields and more efficient in the use of culture environment. However, high inputs of nutrients and limitation on water exchange will create water quality problems that do not always arise in traditional or semi-intensive farming system (Samocha, 2019). If not quickly and correctly addressed, it will lead to the increase of ammonia-nitrogen and nitrite-nitrogen levels (Jescovitch et al. 2018), development of dense microbial community (Ray et al., 2011), outbreaks of shrimp diseases due to the number of contacts (Kautsky at al., 2000; Ruiz-Velazco et al., 2010) and loading of oxygen-consuming organic matter (Direkbusarakom et al., 1998).

The negative correlation between stocking density and growth performance of shrimp has been well established (Sandifer et al., 1996; Moss and Moss. 2004; Arnold et al. 2009). In the biofloc Technology (BFT) trial, density of 300 shrimp/m^2 exhibited superior zootechnical performance compared to 450 shrimp/m^2 (Krummenauer et al., 2011). Meanwhile, the growth and survival of Vannamei cultured in three different densities (100, 200 and 300 shrimp/m^2) using sand ponds with plastic mulch decreased with increasing density (Samadan et al. 2018). In addition, using zero water discharge (ZWD)-recirculating aquaculture system, the optimum performance based on survival, feed conversion ratio (FCR), and productivity was reached at the lowest density of 500 shrimp/m^3 compared to the 750 and 1000 shrimp/m^3 (Suantika et al. 2018).

Interestingly, with proper suplementation of amino acid to fulfill the specific nutrient requirement of Vannamei, the increase in stocking density significantly increased FCR and yield, while reducing shrimp weekly growth and final body weight (Façanha et al., 2016). Therefore, proper combination of stocking density and water quality management system to increase the environmental carrying capacity could a promising strategy to enhance the productivity.

The degradation of environmental carrying capacity conditions, especially dissolved oxygen (D.O) levels, seems to increase with the increases of shrimp density in the ponds. The occurrence of low DO in Southern Brazil was closely associated with shrimp density, where the mean of DO recorded at the density of 450 shrimp/m^2, 1,32 mg/L, was lower than 300 shrimp/m^2 at the level of 2,02 mg/L (Krummenauer et al., 2011). In addition, during spring-summer time of culture period, the lowest DO level was also found in the highest stocking density (Mena-Herrera et al., 2006). Brock and Main (1994) suggested that the D.O level of 0 – 1,5 mg/L are lethal for shrimp and level of 1,7 – 3,0 mg/L resulting in low feed conversion and slow growth. As shrimp technology advances, greater productivity and efficiency with respect to density and water quality conditions are required. The aim of this study was to investigate the effects of density and water quality conditions suplied with air fine disc diffusers on the growth performance of pacific white shrimp *Litopenaeus vannamei* cultured in the concrete tank.

2. Material and methods

This study was performed at the Batam Nara Indonesia (Batam, Riau Island Province, Indonesia). Pacific white shrimp (*L. vannamei*) were obtained from Suri Tani Pemuka (Anyer, West Java, Indonesia), acclimated and nursed in an indoor nursery system for 20 days until reaching a suitable size. At the start of the production trial, juvenile shrimp (mean initial weight of 0,3 g) were then stocked into 32 semi-indoor concrete tanks (8 x 8 x 1 m) at 4 (four) different density: 300, 400, 500 and 600 shrimp/m^2 over 65 days production period. Tanks were filled with saline water (30 – 33 ‰) and suplied with air disc fine bubble diffuser as the primary source of mechanical aeration and one 0,5-hp paddlewheel (Minipadd™) for additional aeration system. Water exchange was performed 5 – 10% throughout the trial for 65 days of culture.

2.1 Feed management

All ponds were offered with the same diet (33 – 35% crude protein, 5% crude lipids) produced by Evergreen (Indonesia Evergreen Agriculture, Lampung Selatan, Indonesia) throughout the growth trial. The amount of feed used in this experiment was calculated based on expected weight gain of 1 g/wk, a feed conversion ratio (FCR) of 1,4 and a weekly mortality of 3 % during grow-out period. During the trial, shrimp were fed six times per day and the daily ration was adjusted based on percentage of body weight after sampling the shrimp on weekly basis

2.2 Growth sampling and water quality

Shrimp were sampled weekly through the remaining production cycle using hand net (0,5 m in diameter and 1 cm mesh) to collect approximately 20 – 30 individuals per tank. Water quality (Dissolved oxygen, pH, temperature, salinity, total dissolved solids, conductivity and oxidative redox potentials) were monitored four times a day (06.00 – 07.00 h; 14.00 – 15.00 h; 17.00 – 18.00 h and 23.00 – 24.00 h) using real-time water quality sensors (Aqua Troll 500, In-Situ Inc., Fort Collins, CO, USA) and managed by AquaEasy Smart Aquaculture apps (BOSCH, Singapore). Secchi disk readings were recorded once a week and ammonia nitrogen (NH3-N) analyzed with Ultraviolet/Visible spectrophotometer (PerkinElmer, Lambda XLS, USA) once a week. Meanwhile, nitrite nitrogen (NO_2-N) and nitrate nitrogen (NO_3-N) were analyzed using HACH DR890 colorimeter (Hach Company, Love- land, CO, USA) twice a week. At the end of growth trial, shrimp were harvested totally, then counted and batched weighed to calculate the final biomass, final weight, percentage weight gain (PWG), feed conversion ratio (FCR), percentage survival (SR), and voluntary feed intake (VFI),

$$\text{PWG} = \frac{(average\ individual\ final\ weight - average\ individual\ initial\ weight)}{(average\ individual\ initial\ weight)} \times 100$$

$$\text{FCR} = \frac{feed\ given\ (g)}{alive\ weigh\ gain\ (g)}$$

$$\text{SR} = \frac{final\ number\ of\ shrimp}{initial\ number\ of\ shrimp} \times 100$$

$$\text{VFI} = \frac{feed\ intake\ (g)}{shrimp}$$

2.3 Statistical analysis

All growth parameters were analyzed using one-way analysis of variance (ANOVA) to determine the significant differences among treatments followed by Tukey's multishrimpe comparison tests to determine the difference between treatment means in each trial. All statistical analyses were conducted using SAS system (V9.4. SAS Institute, Cary, NC, USA).

Results

3.1 Water quality

During the growth trial, the levels of dissolved oxygen, pH, total dissolved solids, oxidative redox potentials, salinity and temperature presented in **Table 1** are within the acceptable range to support the optimal growth of Pacific white shrimp *L. vannamei* (Boyd and Tucker, 1992). The ammonia level ranged from 0,22 ± 0,09; 0,21 ± 0,12; 0,30 ± 0,27; and 0,29 ± 0,44 for 300 shrimp/m^2; 400 shrimp/$m^{2;}$ 500 shrimp/m^2 and 600 shrimp/m^2, respectively. Meanwhile for NO_2-N and NO_3-N parameter, there is an increasing trend for the concentration level as the shrimp density increases.

3.1 Growth Trial

The density treatments affected the growth performance of the shrimp (Table 3). Final weight (g), weight gain (g) and the ADG of the shrimp cultured in the density of 300 Shrimp/m2were significantly higher compared to shrimp cultured in higher density (P<0.05). However, in terms of biomass, the density of 300 shrimp/m^2 yielded the lowest quantity compared to higher density treatments. The feed input increases as the density increases (P<0.05). The FCR and survival rate (%) were not significantly different among the dietary treatments (P<0.05).

Discussion

The results of this study indicated that the *L. vannamei* juvenile grow faster if they are rearing at the lower density. Our study indicated that the growth of 0.17±0.02 g/d was obtained at the stocking density of 300 shrimp/m^2, which is higher than other density treatments. This result similar to the previous reports by Krummenauer et al. (2011) and Suantika et al. (2018). According to Samocha (2019), stocking density has a significant effect to determine the carrying capacity of the tank and crucial for optimizing feed and water quality during the culture period. In addition, McGraw et al. (2001) suggest that the production yields and profitability of Vannamei increases as the carrying capacity and water quality condition increased.

However, evidence showed that the higher biomass will be obtained when *Vannamei* cultured with 600 Shrimp/m2compared to other treatments when rearing intensively in the concrete tank. XX (20XX) reported that carrying capacity is really important to

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Table 1. Summary of water quality characteristics for the four treatments over 65 d of culture period. Data obtained by using sensors and recorded using AquaEasy Smart Aquaculture apps (BOSCH, Singapore). Values are presented as mean ± standard deviation of eight replicates per treatment.

	Treatments			
	300 shrimp/m^2	400 shrimp/m^2	500 shrimp/m^2	600 shrimp/m^2
Dissolved Oxygen (mg/L)				
06.00 – 07.00 h	4,76±0,14	4,82±0,16	4,72±0,33	4,89±0,26
14.00 – 15.00 h	4,99±0,22	4,92±0,18	4,75±0,17	4,70±0,25
17.00 – 18.00 h	5,09±0,24	4,99±0,16	4,76±0,24	4,72±0,19
23.00 – 24.00 h	4,76±0,33	4,81±0,27	4,75±0,33	4,89 ±0,24
pH				
06.00 – 07.00 h	7,33 ± 0,14	7,31 ± 0,28	7,29 ± 0,17	7,28 ± 0,09
14.00 – 15.00 h	7,35 ± 0,19	7,25 ± 0,23	7,23 ± 0,23	7,18 ± 0,11
17.00 – 18.00 h	7,44 ± 0,20	7,24 ± 0,28	7,41 ± 0,26	7,37 ± 0,19
23.00 – 24.00 h	7,29 ± 0,17	7,18 ± 0,38	7,38 ± 0,28	7,24 ± 0,11
Total Dissolved Solids (mg/L)				
06.00 – 07.00 h	31,03 ± 0,11	32,14 ± 2,31	32,19 ± 0,35	32,28 ± 0,49
14.00 – 15.00 h	29,31 ± 2,14	31,27 ± 0,19	32,19 ± 0,43	32,32 ± 0,51
17.00 – 18.00 h	30,04 ± 1,19	30,12 ± 2,52	31,57 ± 1,63	31,62 ± 4,47
23.00 – 24.00 h	30,33 ± 1,28	31,39 ± 0,29	32,39 ± 0,88	32,44 ± 0,31
Oxidative Redox Potential ()				
06.00 – 07.00 h	251,89±32,09	263,28±23,66	261,78±32,61	262,49±25,87
14.00 – 15.00 h	259,27±23,37	264,25±42,22	260,33±11,89	267,14±30,36
17.00 – 18.00 h	260,14±22,58	262,55±19,29	262,47±27,73	261,23±26,55
23.00 – 24.00 h	258,32±41,55	263,18±29,71	262,31±44,03	261,32±32,86

Salinity (‰)				
06.00 – 07.00 h	32,81±0,30	33,05±0,23	32,83±0,60	32,79±0,59
14.00 – 15.00 h	33,07±0,18	32,99±0,72	32,94±1,08	33,15±0,59
17.00 – 18.00 h	32,67±0,78	32,78±0,29	32,67±0,49	32,34±1,08
23.00 – 24.00 h	32,23±1,54	33,19±0,48	33,35±0,28	33,29±0,37
Suhu (^{0} c)				
06.00 – 07.00 h	29,22±0,17	29,14±0,27	29,20±0,18	29,17±0,33
14.00 – 15.00 h	29,58±0,39	29,35±0,11	29,42±0,18	29,40±0,25
17.00 – 18.00 h	29,61±0,22	29,43±0,48	29,42±0,44	29,54±0,52
23.00 – 24.00 h	29,29±0,18	29,19±0,33	29,22±0,19	29,24±0,28

Table 2. Summary of nitrogen characteristics dissolved in the water for the four treatments over 65 d of culture period. Values are presented as mean ± standard deviation of eight replicates per treatment.

		Treatments			
	Unit	300 shrimp/m^2	400 shrimp/m^2	500 shrimp/m^2	600 shrimp/m^2
Ammonia	mg/L	0,22 ± 0,09	0,21 ± 0,12	0,30 ± 0,27	0,29 ± 0,44
Nitrit (NO_2-N)	mg/L	0,09 ± 0,12	0,11 ± 0,08	0,14 ± 0,30	0,14 ± 0,31
Nitrat (NO_3-N)	mg/L	42,88 ± 12,47	64,87 ± 20,56	78,55 ± 28,94	80,94 ± 30,22

Table 3. Growth performance of shrimp (mean initial weight of 0,3 g) offered experimental diets for 65 d. Values represent the mean of eight reshrimpicates. Results in the same columns with different superscript letter are significantly different (*P<0.05*) based on analysis of variance followed by the Tukey's multiple comparison test.

Density (shrimp/m^2)	Biomass (Kg)	Final weight (g)	Weight gain (g)	ADG (g)	Feed input (Kg/tank)	FCR[1]	Survival rate (%)
300	133.2±5.1^{b}	13.0±0.2^{a}	12.5±0.2^{a}	0.17±0.02^{a}	210.00±0.00^{a}	1.58±0.06	53.36±2.17
400	156.9±15.7^{ab}	11.6±0.5^{b}	11.2±0.5^{b}	0.16±0.00^{b}	220.25±36.30^{a}	1.40±0.18	52.98±4.72
500	172.8±10.0^{ab}	10.3±0.4^{c}	10.0±0.4^{c}	0.15±0.01^{c}	245.75±27.29^{a}	1.43±0.20	52.36±2.70
600	198.7±32.0^{ab}	9.3±1.0^{d}	8.8±0.9^{d}	0.14±0.02^{d}	280.88±34.48^{ab}	1.43±0.10	55.94±7.73
P-value	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	0.0850	0.4822
PSE[2]	19.8827	0.5728	0.5515	0.0139	28.5431	0.1468	4.8442
Linear Regression							
r^2	0.6173	0.8762	0.8849	0.7778	0.4858	0.0988	0.0074
p-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0798	0.6388

[1] FCR = Feed conversion ratio

[2] PSE = Pooled standard error

[3] ADG = Average Daily Growth

Figure 1. Logarithmic regression line

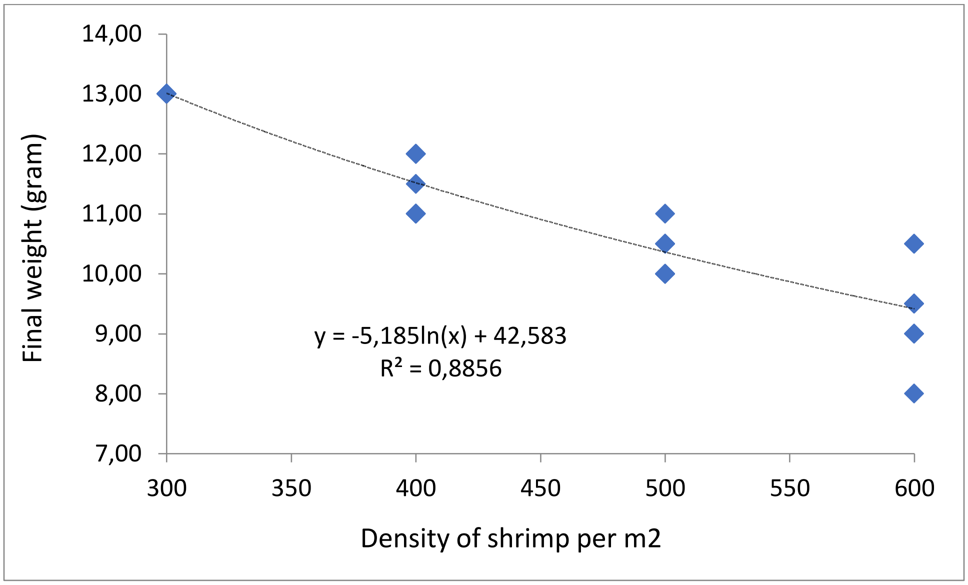

Figure 2. Shrimp growth at four densities measured weekly in 32 concrete tanks during 11-week experimental grow-out. Points are mean values±SD for eight replicates