Production performance of white shrimp *Litopenaeus vannamei* with super-intensive culture on different rearing densities

Kinerja produksi udang vaname *Litopenaeus vannamei* pada budidaya super intensif dengan padat penebaran berbeda

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ABSTRACT

This research aimed to evaluate the production performance of white shrimp *Litopenaeus vannamei* with super-intensive culture on different rearing densities. The research was conducted at PT. Dewi Laut Aquaculture, Cikelet, Garut, West Java. As many of 8 ponds were used and divided into 2 groups based on the stock density of shrimp, 550 ind/m² and 650 ind/m², and reared for 99 days. The results showed that super-intensive shrimp culture at the density of 550–650 ind/m² potentially produced shrimp with average body weight ranged from 15.91–19.31 g, survival rate 62.67–87.95%, growth 0.16 to 0.20 g/day, FCR 1.35–1.66, and productivity reach 5.55–9.19 kg/m². There were no significant differences between the two stocking densities in body weight, growth, and feed conversion performance, while ponds with higher rearing density had better survival and productivity than ponds with lower rearing density. *L. vannamei* cultured at a density of 650 ind/m² produces the best performance and most feasible to be applied in super-intensive white shrimp cultivation.

Keywords: *Litopenaeus vannamei*, super-intensive, high-density, production performance

ABSTRAK

Penelitian ini bertujuan untuk mengevaluasi kinerja produksi udang vaname pada sistem super-intensif dengan padat penebaran berbeda. Penelitian dilaksanakan di tambak PT. Dewi Laut Aquaculture, Cikelet, Garut, Jawa Barat, menggunakan 8 petak tambak. Tambak dibagi menjadi 2 kelompok, masing-masing 4 petak tambak dengan padat tebar udang 550 ekor/m² dan 4 petak tambak lainnya dengan padat tebar 650 ekor/m² dengan masa pemeliharaan 99 hari. Hasil penelitian menunjukkan bahwa budidaya udang vaname pada sistem super-intensif dengan padat tebar 550–650 ekor/m² dapat menghasilkan udang dengan bobot rata-rata berkisar antara 15.91–19.31 g, sintasan 62.67–87.95%, pertumbuhan 0.16–0.20 g/hari, konversi pakan (FCR) 1.35–1.66, dan produktivitas mencapai 5.55–9.19 kg/m². Tidak ada perbedaan nyata antara kedua padat penebaran pada kinerja bobot, pertumbuhan harian, dan FCR; sementara tambak dengan kepadatan tinggi memiliki nilai sintasan dan produktivitas yang lebih tinggi dari tambak dengan kepadatan rendah. Padat penebaran 650 ekor/m² menghasilkan kinerja produksi terbaik dan paling layak untuk diaplikasikan dalam budidaya udang vaname super-intensif.

Kata kunci: *Litopenaeus vannamei*, padat tebar tinggi, super-intensif, kinerja produksi
INTRODUCTION

White shrimp is one of the export commodities with high economical value (Herdianti et al., 2015). Global white shrimp market demand is estimated to reach 5 million tons each year, while the industry is lacking the supply. Global production of shrimp is only 3.6 million tons and 2.37 million tons of it is white shrimp Litopenaeus vannamei which reared in brackish water (FAO GLOBEFISH, 2015). White shrimp production in Indonesia has supported the whole industry of white shrimp culture (Gunarto et al., 2012). White shrimp is a famous species amongst shrimp farmers. It grows faster (Purba, 2012), relatively resistant to disease (Schock et al., 2013; Umiliana et al., 2016), high survival rate, a wide range of salinity tolerance (4–32 g/L) (Maicá et al., 2014), and travels around the water column (Ernawati & Rochmady, 2017). It also exhibits efficient feeding (Umiliana et al., 2016), can rear in high density (Wasielesky et al., 2013), and high composition of meat (66–68%) compared to the tiger shrimp (62%) (Purba, 2012).

The high market demand of vannamei encourages the development of white shrimp culture, one of them is a floating cage net (Zarain-Herzberg et al., 2010; Effendi et al., 2016) and super-intensive culture. Various shrimp production is well-developing, starting from the high surface area and low-density culture to technology-based cultures, such as fertilization, feedings trays, and high stock density culture (Wasielesky et al., 2006). Super-culture is the main focus of the future aquaculture using low volume, high stock density (Syah et al., 2017; Krummenauer et al., 2011; Wasielesky et al., 2013), high productivity (Krummenauer et al., 2011; Syah et al., 2017), low wastewater (Syah et al., 2017), and equipped with quarantine pond to treat the wastewater (Syah et al., 2017).

Super-intensive shrimp culture is usually conducted in a small container with high density and a short-term rearing period (less than 40 days) (Wasielesky et al., 2006; Maicá et al., 2014). The latter method is combined with the two-step method, i.e. high density in the nursery phase and after several days, the shrimp will be moved to the grow-out phase with lower density (Vinathea et al., 2010; Wasielesky et al., 2013; Schock et al., 2013).

White shrimp culture with high density and long rearing period was done by Krummenauer et al. (2011) with 150,450 individuals/m² for 120 days. A super-intensive culture is expected to increase productivity. However, there is a certain level when the carrying capacity reaches the limit (Syah et al., 2017). An excessive density influences the whole culture system which leads to failure as a consequence of enormous waste. This study was expected to evaluate the production performance of white shrimp in a super-intensive culture with two different densities as a standard to determine an optimal density of white shrimp culture.

MATERIALS AND METHODS

This study was held in September–December 2016. The shrimp culture was conducted in PT. Dewi Laut Aquaculture, Garut, West Java. It used eight ponds with 400 m² of average width and 3 m of depth. The experimental ponds were categorized into two groups, i.e. four ponds with 550 individuals/m² (T550) and four ponds with 650 individuals/m² (T650). The result by Krummenaur et al. (2011) was used to determine the treatments in this study. It was possible to increase the density beyond 450 individuals/m² due to the sufficient result by Krummenaur et al. (2011).

The pond construction was covered by HDPE plastic with 0.75 mm of thickness. It was also furnished with a central drain, one blower with 7.5 horsepower (HP), and four paddle wheel with 1 HP each (Figure 1). A 1 HP of paddle wheel facilitates 16 kg of feeding per day with maintaining dissolved oxygen content amongst 3 mg/L and targeted biomass around 550–600 kg (Hopkins et al., 1991). The water level was filled up to 2.5 m depth, followed by 15 mg/L of trichloroisocyanuric acid (TCCA), 25 mg/L of saponin, 1 mg/L ZA fertilizer, 1.5 mg/L of molasses, 5 mg/L of dolomite, and 0.1 g/m³ of commercial probiotics (Bacillus sp., Thiofocillus sp., Nitrosomonas sp., and Nitrobacter sp.) to grow plankton and form flocs for 12 days. Particularly, the probiotics were delivered every two weeks during the culture.

The tested seed used in this study was specific pathogen-free (SPF) post larvae 9 from Lampung Province. They were reared in the pond for 100 days based on the treatment using a semifloc system. The tested post-larvae were fed using crumble feed with 40% of protein content in the initial phase, then changed to a pellet with 36% of protein content after 20 days. It was based on the standard of white shrimp farming. In the first month of study, the blind feeding method was applied. Blind feeding is established according
to survival and average weight estimation, also feeding rate (15% of total biomass). The percentage was declined to 5%, 4%, and 3% for the second, third, and fourth month, respectively. Feeding frequency was carried out six times a day. During the rearing period, water discharge and siphoning were completed regularly to eliminate uneaten feed and organic waste on the bottom of the pond. Partial harvest was conducted as many as 25% of the biomass on day 60 dan 75. On the contrary, the total harvest was done on day 99.

**Tested parameters**

The tested parameters consisted of average body weight (ABW), average daily weight (ADG), survival, feed conversion ratio (FCR), and productivity. ABW and ADG were measured regularly after 30 days of rearing by collecting 30–40 shrimp in each pond every seven days. Survival, FCR, and productivity were calculated at the end of the study. The following formulas are used to calculate ABW, ADG, survival, FCR, and productivity (Maicá *et al.*, 2014).

**Average body weight (ABW)**

ABW is a ratio between individual bodyweight and population weight. It is calculated using the following formula.

\[
ABW = \frac{\sum \text{shrimp weight (g)}}{\sum \text{shrimp population (g)}}
\]

**Average daily gain (ADG)**

ADG is daily weight addition in a certain time. It is calculated using the formula below.

\[
ADG = \frac{\text{ABW}_f - \text{ABW}_i}{H}
\]

ABW<sub>f</sub> = final average weight (g)
ABW<sub>i</sub> = initial average weight (g)
H = rearing period (day)

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**Table 1. Shrimp population and density each ponds.**

| No | Pond code | Wide (m<sup>2</sup>) | Population (individual) | Density (ind/m<sup>2</sup>) |
|----|-----------|----------------------|-------------------------|----------------------------|
| **Group I (T550)** | | | | |
| 1 | A2 | 407 | 222,528 | 547 |
| 2 | A3 | 410 | 222,528 | 543 |
| 3 | A5 | 406 | 226,452 | 558 |
| 4 | A10 | 408 | 225,122 | 552 |
| **Average** | | 408 | 224,158 | 550 ± 6.49 |
| **Group II (T650)** | | | | |
| 1 | A2 | 395 | 256,891 | 650 |
| 2 | A3 | 410 | 266,585 | 650 |
| 3 | A5 | 395 | 257,580 | 652 |
| 4 | A10 | 437 | 282,384 | 646 |
| **Average** | | 409 | 265,860 | 650 ± 2.50 |
**Survival rate**

Survival is the percentage of the survived population at the end of the study. It was calculated by dividing the final population and initial population.

\[ SR = \frac{N_t}{No} \times 100 \]

**Feed conversion ratio (FCR)**

FCR is a mathematical relationship between total feed and biomass gained by consuming it. It was calculated using the following formula.

**Productivity**

In this study, productivity was measured based on a unit of pond-wide. The following formula was used to determine productivity. Water quality parameters in this study were temperature, dissolved oxygen (DO), pH, salinity, total ammonia nitrogen (TAN), nitrite (NO\(^2\)-), nitrate (NO\(^3\)-), phosphate (PO\(_4\)), and total organic matter (TOM). Temperature, DO, and pH was measured daily every morning, afternoon, and evening. Meanwhile, salinity, TAN, phosphate, and TOM were measured every week, twice a day.

**Data analysis**

The growth parameters were analyzed statistically using Repeated Measures ANOVA through IBM SPSS Statistics 20 to determine the significant difference amongst treatments. The rest of the data were described descriptively to discover the biological response of the white shrimp and characteristics of the aquatic environment.

**RESULTS AND DISCUSSION**

The T550 treatment resulted in survival ranged from 62.67–87.95% and ABW was 15.91–19.31 g. The ADG, FCR, and productivity ranged from 0.16–0.20 g/day, 1.35–1.66, and 5.55–7.54 kg/m\(^2\), respectively. Meanwhile, the T650 treatment presented 79.97–87.34% of survival, 16.50–17.91 g of ABW, and 0.17–0.19 g/day of ADG. FCR and productivity ranged from 1.38–1.49 and 7.87–9.19 kg/m\(^2\) (Table 2). Those results were in line with Krummenauer et al. (2011) who conducted white shrimp culture in a biofloc system with 150, 300, and 450 ind/m\(^2\) of density for 120 days. He reported that the survival was around 75–92 %, ABW was 9–16.8 g, ADG ranged from 0.07–0.13 g/day, FCR extended in 1.29–2.41, and productivity differed between 2.15–4.09 kg/m\(^2\).

The water quality parameter indicated a supportive environment condition to the white shrimp. There was no intense difference amongst the treatment. The temperature was relatively 26–32°C, dissolved oxygen was 4.0–8.3 mg/L, and pH was 7.3–8.9. Total ammonia nitrogen, nitrite, nitrate, phosphate, and organic matter extended from 0.5–5 mg/L, 0.1–25 mg/L, 1–150 mg/L, 0.3–3 mg/L, and 38–126 mg/L, respectively (Table 3).

### Table 2. White shrimp production in super intensive system

| Density (ind/m\(^2\)) | Pond ID | Biomass (kg) | SR (%) | ABW (g) | ADG (g) | FCR | Productivity (kg/m\(^2\)) |
|------------------------|---------|--------------|--------|---------|---------|-----|--------------------------|
| 550                    | A2      | 3.069.11     | 76.60  | 19.31   | 0.20    | 1.35| 7.54                     |
|                        | A3      | 2.889.08     | 73.12  | 19.24   | 0.19    | 1.45| 7.05                     |
|                        | A5      | 2.255.03     | 62.67  | 17.29   | 0.17    | 1.66| 5.55                     |
|                        | A10     | 2.924.08     | 87.95  | 15.91   | 0.16    | 1.36| 7.17                     |
| **Average**            | **2.784.33 ± 361.37** | **75.09 ± 10.42** | 17.93 ± 1.64 | 0.18 ± 0.02 | 1.45 ± 0.14 | 6.83 ± 0.87 |

| 650                    | B4      | 3.109.53     | 79.97  | 16.94   | 0.18    | 1.46| 7.87                     |
|                        | B7      | 3.400.39     | 80.22  | 17.72   | 0.19    | 1.43| 8.29                     |
|                        | B8      | 3.629.34     | 87.34  | 17.91   | 0.18    | 1.38| 9.19                     |
|                        | B10     | 3.574.08     | 85.04  | 16.50   | 0.17    | 1.49| 8.18                     |
| **Average**            | **3.428.34 ± 233.85** | **83.14 ± 3.64** | 17.27 ± 0.66 | 0.18 ± 0.01 | 1.44 ± 0.05 | 8.38 ± 0.57 |

Note: Different superscript letter in the same column indicates significant different (P<0.05).
According to Table 4, it was clearly described that there was no significant difference amongst treatment in ABW, ADG, and FCR (P>0.05). On the contrary, survival and productivity indicated a significant difference amongst treatments (P<0.05). The T550 treatment presented a slightly greater result compared to the T650. Even though, there was no significant result on both ABW and ADG (Table 4). A tolerable environment was assumed to support the white shrimp culture.

Figure 2 explained that the daily growth of the white shrimp was relatively identical until day 40. Some sort of contrast were started to appear after day 40 that leads to a greater result in T550. The growth of white shrimp was straightly affected by the density. When the density went higher, the growth was likely lessened. Several former studies support the result, i.e. Balakrishnan et al. (2011), Krishna et al. (2015), Budiardi et al. (2005), and Krummenauer et al. (2011).

Both treatments presented greater ADG (0.18 ± 0.02 g/day) compared to Krummenauer et al. (2011) (0.12, 0.13, and 0.07 g/day) with 150, 300, and 450 ind/m² of density. A similar result was described by Syah et al. (2017) (0.20 ± 0.01 g/day) who reared white shrimp in 700, 1000, and 1200 ind/m² of density. Those results indicated that white shrimp was relatively tolerant towards high density. Budiardi et al. (2005) stated that the density will affect the competition amongst individuals, in terms of area, food, and oxygen. However, the ability of white shrimp to utilize the entire water column, tolerable water condition, and adequate nutrition supply also positively contributed to weight gain without being disturbed by the density (Syah et al., 2017). Wasielesky et al. (2013) reported that the aborted white shrimp for 35 days which reared in 1500–6000 ind/m² reported no significant weight gain compared to the 300 ind/m² of density.

The T550 treatment produced lower survival than the T650 treatment. This opposed the result by Budiardi et al. (2005), Krummenauer et al. (2011), Krishna et al. (2015), and Syah et al. (2017) who confirmed that higher density would lead to lower survival. Nevertheless, diverse survival could appear as well, e.g. Ernawati and Rochmady (2017). They used various densities, i.e. 9, 14, 19 ind/container and the survival was 70.37%, 78.57%, and 74.27%, respectively. Ernawati and Rochmady (2017) suggested that the highest survival was considered as the

Table 3. Water quality result.

| Water quality parameter          | Treatment | Threshold | Reference          |
|----------------------------------|-----------|-----------|--------------------|
| Temperature (°C)                 | T550: 26–32 | T650: 26–32 | 20–32              | González et al., 2010 |
| Dissolved Oxygen (mg/L)          | 4.00–6.80 | 4.0–8.3   | ≥ 4                | Cobo et al., 2014     |
| pH                               | 7.5–8.8   | 7.3–8.9   | 6–9                | Boyd, 1989            |
| Salinity (g/L)                   | 21–26     | 21–26     | 20–45              | Chong-Robles et al., 2014 |
| TAN (mg/L)                       | 0.5–5     | 0.5–5     | ≤ 13.2             | Cobo et al., 2014     |
| Nitrite (mg/L)                   | 0.1–25    | 0.1–25    | ≤ 163.3            | Schuler et al., 2010  |
| Nitrate (mg/L)                   | 1–150     | 1–125     | ≤ 220              | Khun et al., 2010     |
| Phosphate (mg/L)                 | 0.3–3     | 0.3–3     | ≤ 390.55           | Na et al., 2009       |
| Total organic matter (mg/L)      | 38–126    | 25–125    | < 500              | Gaona et al., 2011    |

Table 4. Production performance of white shrimp with different densities.

| Production performance            | Treatment | T550      | T650      |
|-----------------------------------|-----------|-----------|-----------|
| Survival rate/SR (%)              | 75.09 ± 10.42a | 83.14 ± 3.64a |
| Average body weight/ABW (g)       | 17.93 ± 1.64a | 17.27 ± 0.66a |
| Average daily growth/ADG (g/day)  | 0.18 ± 0.02a | 0.18 ± 0.01a |
| Feed conversion ratio/FCR         | 1.45 ± 0.14a | 1.44 ± 0.05a |
| Productivity (kg/m²)              | 6.83 ± 0.87a | 8.38 ± 0.57a |

Note: Different superscript letter in the same row indicates significant different (P<0.05).
optimum survival because no food and movement competition triggered cannibalism amongst individuals. In this study, the T650 treatment was considered as an acceptable density for white shrimp culture. Also, the dissolved oxygen and nitrate in the T650 treatment were slightly better.

The FCR in this study did not differ significantly (P>0.05) amongst treatments (Table 4). It was different from Budiardi et al. (2005) who reported that shrimp that culture in low density (72–73 ind/m²) showed lower FCR compared to the higher density (93–105 ind/m²). However, various FCR was also shown in several studies, such as Krummenauer et al. (2011) with 150, 300, and 450 ind/m² of stocking density and Syah et al. (2017) with 750, 1000, and 1250 ind/m². Live feed supply tends to decrease when the density grows higher so that shrimp will rely on the artificial feed even more (Budiardi et al., 2008; Mangampa & Suwoyo, 2010). As a result, shrimp culture with high density is required to estimate the population accurately. It is essential to avoid excessive feeding that possibly leads to high FCR.

Productivity is the harvested biomass in a certain wide unit. Productivity increases along with biomass. In this study, the T650 treatment showed greater productivity compared to the T550. On the contrary, Budiardi et al. (2005) reported that lower density showed higher productivity. In this case, the T650 treatment still presented excellent productivity, so that the biomass was high as well. Fleckenstein et al. (2020) stated that stocking density directly affected shrimp production significantly. It was possible because the water quality parameter in the T650 still supported the shrimp culture system, especially dissolved oxygen, temperature, pH, and salinity (Table 3). It showed that the productivity strongly increased along with the density continuously until a certain level of carrying capacity in an aquatic environment.

Ammonia-nitrogen content and organic matter in both treatments were relatively high. Although it was tolerable for shrimp culture (Cobo et al., 2014; Schuler et al., 2010). Ammonia is a toxic output of organic matter demolishing. Ammonia toxicity declines when the dissolved oxygen raising (Barbieri, 2010). A high level of ammonia is distinctly influenced by the density due to the high waste of feces and uneaten feed. Super-intensive culture often faces eutrophication due to excessive nutrient and organic waste (Nguyen et al., 2019; Nguyen et al., 2020). Nevertheless, nitrification was run by the bacteria to maintain the ammonia-nitrogen content. Nitrosomonas sp. and Nitrobacter sp. oxidated ammonia-nitrogen, so that it changed into nitrite and nitrate. Nitrate is the final result of nitrification which later will be benefited by phytoplankton (Herdianti et al., 2015).

Thereafter, high density demands more feed. Excessive feed triggers higher pollutants, e.g. uneaten feed and metabolic waste (Budiardi et al., 2005). Organic matter accumulation produces ionic iron, hydrogen sulfide, and reduced compounds, which are lethal for shrimp Boyd (1989). In line with Budiardi et al. (2005), Khoa et al. (2020) stated that high density induced a higher concentration of microbes due to the abundant nutrition in the water. Dissolved oxygen demand

![Figure 2. White shrimp growth in various density](image-url)
and suspended solid will elevate and the turbidity will also affect shrimp growth (Fleckenstein et al., 2020). However, the water quality results in this study were kept in tolerable range, so that eutrophication in the pond ecosystem did not influence shrimp survival, growth, and biomass significantly (González et al., 2010; Cobo et al., 2014; Boyd, 1989; Chong-Robles et al., 2014; Schuler et al., 2010; Khun et al., 2010; Na et al., 2009; Gaona et al., 2011). Gaona et al. (2011) declared that organic matter can be reduced when the culture system is well-managed. A decreased organic waste will lead to the excellent water condition. Furthermore, shrimp culture with a greater growth will be fully supported (Gaona et al., 2011). Overall, we can conclude that high-density shrimp culture was applicable with advanced environmental management.

CONCLUSION

There was no significant difference amongst treatments in terms of ABW, ADG, and FCR. On the contrary, survival and productivity showed a significant result in the T650 treatment. We can conclude that the T650 treatment was considered applicable in super-intensive shrimp culture.

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